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ABSTRACT

This curriculum guide consists of seven modules on motors and controls, one of the three divisions of the standardized trade electricity curriculum in high schools in New York City. The seven modules cover the following subjects: energy conservation wiring, direct current (DC) motor repair and rewinding, DC motor controls, alternating current (AC) motor repair and rewinding, AC motor controls, industrial electronics, and transformers. Each unit is comprised of performance objectives and tasks to meet the performance objectives, keyed to teaching content. Teaching content is offered in a three-column arrangement consisting of the tasks, development of technical skills, and development of related information (reinforcement of basic skills). Some of the units contain line drawings. A section that provides suggestions for integrating basic skills instruction with the technical content also is offered. Appendixes to the guide contain a bibliography, a sample lesson plan, and a blank student evaluation report. (KC)

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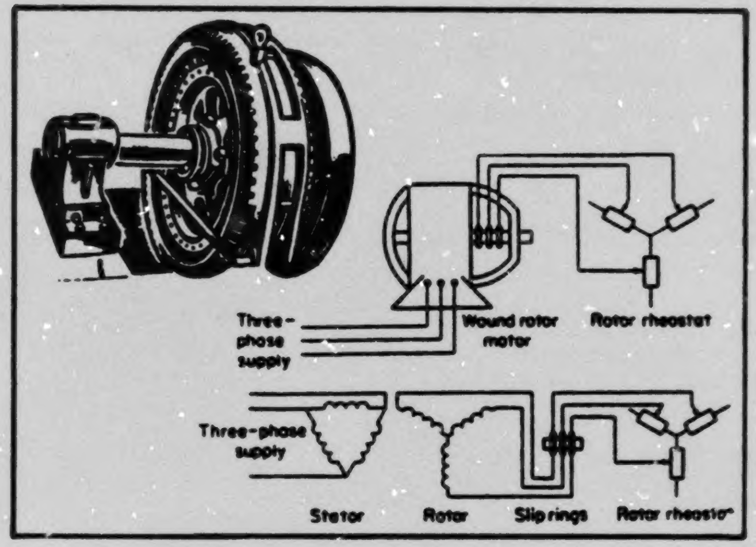
TRADE ELECTRICITY
MOTORS & CONTROLS LEVEL 3
STANDARDIZED CURRICULUM


Three-phase supply
Wound rotor motor
Rotor rheostat
Three-phase supply
Stator
Rotor
Slip rings
Rotor rheostat

NEW YORK CITY PUBLIC SCHOOLS

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Foreword

A Standardized Trade Electricity Curriculum, Motors and Controls is designed to provide vocational training for young persons of high school age who have shown an aptitude for the electrical trades and have expressed a desire to enter the field of electrical trades. This curriculum also may be used fully or in part in alternate programs, such as Shared Instruction and After School Occupational Skills. In addition, individual modules can be used in special education programs and adult occupational training.

The content has been organized into three major divisions: Signal Wiring - Level One; Lighting - Level Two; Motors and Controls - Level Three. Each division contains a number of specific modules with several jobs within each module. The entire curriculum is designed to be taught in 1200 hours. The third division is comprised of several optional modules enabling schools to select modules which best suit their needs, fully or in part.

The aim of the total curriculum is to provide a broad foundation of basic skills and information to enable interested students to enter the electrical industry as workers and to pursue advanced training.

Acknowledgments

The Standardized Trade Electricity Curriculum, Motors and Controls - Level Three was developed for use in the New York City High Schools during the OCE 1981 Summer Curriculum Project. The project was initiated by the Office of Occupational and Career Education, George R. Quarles, Chief Administrator; Dr. Howard Friedman, Deputy Administrator; and Mary Gaskin, Director of Support Services. The development of instructional guides for standardizing vocational programs was under the direction of the Bureau of Trade and Technical Education, John B. Vitale, Assistant Director and the Occupational Curriculum Unit, Anne McCarthy Consultant.

Overall supervision was provided by the Occupational Curriculum Unit, Jack H. Dixon, Coordinator, with the assistance of Dr. Arthur Golomb, Curriculum Specialist and Brenda Fryson, Basic Skills Specialist.

Members of the curriculum writing committee were Daniel S. Immordino, Assistant Principal-Supervision, Electrical Installation and Practice at William E. Grady Vocational/Technical High School and Saverio Sandonato, Assistant Principal-Supervision, Building Trades at Thomas A. Edison Vocational/Technical High School. Milton Stein, Teacher of Climate Control, assisted in the writing of Unit I: Energy Conservation Wiring. The text was edited by Benita Daniels. Illustrations were furnished by Peter Battaglia, Assistant Principal-Supervision, Related Technical Subjects, Alexander Hamilton Vocational/Technical High School.

The bulletin was reviewed and prepared for printing by members of the Editorial/Production Unit of the Office of Curriculum Development and Support, Dr. Morris Freedman, Director. OCDS is a part of the Division of Curriculum and Instruction, Charlotte Frank, Executive Director.

Credits

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SUGGESTIONS FOR IMPLEMENTATION

STRATEGIES FOR REINFORCING RELATED MATHEMATICS, READING AND COMMUNICATION SKILLS THROUGH OCCUPATIONAL EDUCATION

REINFORCING RELATED BASIC SKILLS

Increased employer demands, coupled with fierce competition for employment in many occupational areas, have made it vital that students moving into the job arena be totally prepared to obtain and hold jobs. The experienced vocational instructor has long understood that preparation for the job market does not end with the development of hands-on skills. The incorporation of related reading, communications and mathematics skills into the Trade Electricity course of study represents a comprehensive approach to teaching which will enhance opportunities for future job success.

The strategies and activities which can be designed for the purpose of basic skills reinforcement are limited only by the imagination of the individual instructor. Each instructor must decide, based upon the needs of his/her students, what methods work best. Traditional student participatory activities such as preparing reports, viewing films, taking field trips, planning and completing electrical projects, all present opportunities for basic skills reinforcement.

This curriculum guide in Trade Electricity clearly outlines the hands-on operations which should be covered during the course work. The second and third columns of this guide also include references to tasks which require a certain level of competency in mathematics, reading and communications, if the student is to fully grasp the course content. The items provide opportunity for REVIEW and PRACTICE of related basic skills within the confines of the shop setting.

The instructor of trade electricity can use these topics and subtopics to build basic skills activities into daily lessons. It is important to note that the primary responsibility for TEACHING academic competencies rests with the teachers of those subjects. However, the concept of REINFORCEMENT allows the teacher of Trade Electricity to focus on those reading, mathematics and communications skills which relate directly to the trade area.

The concept of reinforcement encompasses the two types of teaching strategies mentioned earlier: REVIEW and PRACTICE.

Review

Basic skills review exercises in the electrical shop setting can take the form of "mini-lessons" which can be presented as an integral part of class sessions devoted to "shop theory" or "related technical information." These activities should be planned in conjunction with the development of the hands-on skills.

A review of the Trade Electricity course of study will reveal mathematics, reading and communication skills which will help to maximize student performance or understanding of a particular task or topic. Each of these skills can then be reinforced at the most appropriate times during the course work. For example, a review of Ohm's Law may also involve a review of:

- -problem-solving techniques
- -methods of working with formulas
- -multiplication and division of fractions

These math skills can again be reviewed when other electrical formulas are introduced.

Examples of Related Basic Skills Review Activities

Review Ohm's Law
Discuss how to calculate voltage drop in a series circuit
$E = I \times R$

Review reading skills: reading and understanding technical data
Develop hints for interpreting technical data
Examples:
- -Look up any unfamiliar words
- -Try to put complicated passages into your own words.

Practice

Practice exercises provide opportunity for the student to develop and examine the skill which has been reviewed during the class session. Here are some examples of the types of activities which encompass both basic skills reinforcement and job preparation:

- .using the correct names of tools and machines while performing hands-on operations
- .using actual materials (metal, wood, etc.) for accurate measuring
- .using order forms and message blanks to reinforce spelling and writing skills
- .using sample civil service examinations to improve test-taking techniques
- .using proofreading methods to check sentence structure and punctuation

With the increased emphasis on strengthening basic skills, many teachers have begun to compile comprehensive files of worksheets/assignment sheets which they use in a variety of teaching situations. These exercises often are used for homework assignments, student assessment or classroom practice.

The two assignment sheets which follow illustrate how information related directly to the electrical trades can be used to develop student worksheets which help to reinforce basic skills. In the first example, the student clearly sees that ability to read and interpret information presented in chart form is a job-related skill which must be mastered. The second assignment sheet reminds the student of the importance of systematic note-taking in the classroom as well as in some on-the-job situations.

Sample Assignment Sheet

TRADE ABBREVIATIONS AND SYMBOLS

As you have seen, many abbreviations and symbols are used in the electrical trade. You must be familiar with these abbreviations and symbols and know how to write them correctly if you plan to work in this field.

DIRECTIONS: Complete the exercise by filling in the missing information. Double-check your work from your classroom notes.

	TERM	ABBREVIATION/SYMBOL
1.	Direct Current	
2.	National Electral Code	
3.	Constant Ringing Drop	
4.	Kilowatt	
5.	Volt	
6.	Horsepower	
7.	Holding Coil	
8.	Open Coil	
9.	Grounded Coil	
10.	Shorted Coil	

Sample Assignment Sheet

FUEL WASTE DUE TO HIGH NIGHT SETTINGS

DIRECTIONS: Study the information presented in the chart. Answer each question by referring to the data in the chart

FUEL WASTE DUE TO HIGH NIGHT SETTINGS

Lowered Night Temperature degrees F	Savings in Oil (per cent) when Temperature is Lowered at Night			
	4 hours	8 hours	12 hours	16 hours
70	0	0	0	0
65	2.5	5	7.5	9.5
60	5	9.5	14.5	19.5
55	7.5	14.5	21.5	28.5
50	9.5	19.5	28.5	38.5

1. When the night temperature is lowered to 60° for 8 hours what percentage of oil is saved?________.
2. What is the difference in savings for 4 hour period when the temperature is set at 65° and 55°?
   __________.
3. A 21.5% savings in oil can be realized when the temperature is set at_____degrees F for_____hours.
4. When the night temperature is lowered to 55° for 12 hours, there is a_____% savings in oil.
5. Why do you think there is no oil savings when the temperature is set at 70°F? (Answer in a complete sentence) ____
   ____.

BASIC SKILLS OVERVIEW

For purposes of establishing a workable and realistic teaching framework for the instructor, basic skills may be defined as those reading, mathematics and communication skills which are essential to:

-the student's overall understanding of the tasks, knowledges and appreciations which form the the course of study

-the student's ability to eventually perform satisfactorily as a worker in a job setting.

-the student's ability to pass:

Standardized academic examinations
Occupational licensing examinations

Specifically, these skills may be viewed within the following broad categories:

-READING COMPREHENSION

-VOCABULARY DEVELOPMENT

-COMMUNICATIONS

  -WRITING
  -SPEAKING and LISTENING

-MATHEMATICS

The chart on the following page lists several subskills under each broad category. These subskills denote areas in which reinforcement would be most pertinent to students enrolled in vocational courses. Following the chart are discussions of each of the major basic skills categories and methods by which these subskills can be presented for review and practice throughout the course.

RELATED BASIC SKILLS

READING COMPREHENSION SKILLS

- Understanding written directions
- Reading for location of specific details
- Reading for understanding of overall concept or idea
- Reading to infer meaning
- Learning technical terms
- Learning to sound out words
- Learning word parts (related roots, prefixes and suffixes)

MATHEMATICS SKILLS

- Counting
- Adding whole numbers, fractions, decimals
- Subtracting whole numbers, fractions, decimals
- Multiplying whole numbers, fractions, decimals
- Dividing whole numbers, fractions, decimals
- Problem-solving (using equations, formulas, geometric principles)
- Problem-solving (understanding related word problems
- Understanding the metric system

WRITING SKILLS

- Using correct capitalization and punctuation
- Understanding sentence structure (basic grammatical concepts)
- Using technical terms
- Learning helpful spelling rules
- Learning to sound out words
- Using the dictionary

SPEAKING AND LISTENING SKILLS

- Using standard English
- Practicing appropriate voice volume
- Relating and receiving directions
- Relating and receiving specific details
- Interpreting information and meaning
- Drawing conclusions
- Relating and receiving non-verbal messages
- Using technical terms

Writing Skills

By emphasizing the mechanics of spelling, punctuation, word usage and sentence structure in a variety of simulated work-related situations, the instructor will be able to help students understand the practicality of what they often perceive as an abstract notion which has no meani in the real world.

Each pre-vocational and occupational subject will require a different level of proficiency with respect to writing skills. As needs arise, practice can be given with particular rules tha are used frequently. Thus, the instructor must make an initial analysis of the writing skills which are required for adequate job performance in the electrical trades. There are, however, common areas of student deficiency, which include the inability to:

-Compose complete sentences

-Use words correctly in sentences (grammar)

-Use words appropriately (including technical terms)

-Spell words correctly

-Punctuate sentences correctly

-Write legibly

Improvement in these area is based upon the systematic inclusion of these skills in classro activities. The use of actual materials such as order blanks, sales slips, work orders and bills of materials will require the student to apply basic writing standards to job-related situations. If students understand from the outset that all written work will be checked for adherence to these standards, they will be more conscious of not only what they write, *but how they write it.*

Reading Comprehension

The advantage of having available printed material which is of high student interest is an invaluable aid in the reinforcement of reading comprehension skills. Those students who have experienced difficulties with reading in other areas can be motivated and provided with numerou opportunities for achievement. Other students will be fascinated with the variety of reading materials which are pertient to the electrical trades.

Textbook passages, professional journals, catalogs and schematic drawings are examples of types of reading materials which may be used. From these, reading comprehension exercises whic emphasize specific skill reinforcement may be developed.

Several strategies can be utilized to assist in strengthening reading competencies:

- -Emphasizing the importance of improving specific comprehension skills
- -Using a wide variety of printed materials, including schematic drawings and municipal codes
- -Constructing a variety of comprehension questions which are keyed to related reading materials
- -Introducing unfamiliar terms prior to making a reading assignment
- -Assigning short reading passages for thorough understanding
- -Reviewing basic components of electrical codes and other standard references
- -Emphasizing good study skills
- -Emphasizing concise note-taking

Vocabulary Development

Each professional area has its own unique set of terms. These are highly specialized words and phrases which are peculiar to the particular profession. Mastery of these terms contributes directly to a more thorough understanding of the course work.

It is suggested that terms related to the electrical trades be used as the basis for the development of individual notebook glossaries. Thus, as new topics are presented, the related vocabulary is introduced as an integral part of the overall lessons. It is more effective to explore six or seven new words or phrases within the context of a skills lesson than to present twenty or thirty such terms in an isolated and unrelated learning situation. The systematic building of a notebook glossary allows the instructor to easily review key terms and to reinforce spelling, pronunciation and usage (oral and written).

As a result of this approach to new terminology, the instructor will find it possible to emphasize more general areas of vocabulary development. These include:

-Recognition of common prefixes, suffixes and roots

-Division of complex words into syllables

-Identification of commonalities in spelling

-Use of the dictionary and other reference materials

(Here, the student is encouraged to decide upon the meaning of an unfamiliar word based upon his/her knowledge of other words in the sentence.)

Oral Communications (Speaking and Listening)

Perhaps the most overlooked components in the basic skills compendium are the speaking and listening skills. Yet, competency in these areas is critical to future job success. Additionally the very nature of the learning activities requires students to employ these critical skills.

By building an awareness of common errors and focusing on the dynamics involved, the instructor can assist in developing solid communication skills. For example, following oral directions is an activity which is a fundamental component of the teaching/learning process. This process includes several clearly defined steps which can be presented for review and practice. They are:

- Listening to and interpreting the entire explanation
- Understanding and determining the steps involved
- Completing and checking each step before proceeding to the next
- Verifying (checking) the entire action taken and the results obtained

Classroom simulations which approximate actual on-the-job situations lend excitement and realism to the systematic practice which is neccessary for achievement in this area. These activities can be enhanced by use of the tape recorder and video tapes which allows the students to hear and see themselves in various situations. Even more germane to student performance is the example set by the instructor. By stressing acceptable English, speaking slowly and distinctly and responding carefully to questions, the teacher sets the standards which will carry over into other life experiences.

Mathematics Skills

Instruction which draws on realistic settings and problems in strengthening computational skills helps students transfer this learning to new situations. Additionally, the realization that most students will eventually become workers, taxpayers and consumers, opens up a wide range of possibilities for demonstrating the importance and practicality of possessing a sound background in mathematics.

Many students exhibit a fear of mathematics. The exploration of mathematical concepts and operations in the electrical shop can provide them with opportunities for achievement in an area of critical need.

The key to student achievement is the presentation of the skills in easily manageable components. The use of teacher-made assignment sheets and/or career-oriented workbooks is an effective means of practice and review which need not detract from classroom time.

Mathematical operations lend themselves to efficient division into subskills which can be explored as a part of the total lesson. The following suggestions may assist the instructor in the reinforcement of a related computational skill.

-Present the concept within the context of a vocationally-related-application
-Review the fundamental steps in the operation
-Provide opportunity for group discussion and practice
-Provide assignments which include vocationally-related word problems

DENTIFYING RELATED BASIC SKILLS

This basic skills checklist will help in the identification of discreet subskills and on-the-job applications which are most relevant to Trade Electricity.

Basic Skills Checklist

Trade Electricity

. What specific math skills should be emphasized during the teaching of this course?

( ) Adding whole numbers_____ fractions_____ decimals_____

( ) Subtracting whole numbers_____ fractions_____ decimals_____

( ) Multiplying of whole numbers_____ fractions_____ decimals_____

( ) Dividing of whole numbers_____ fractions_____ decimals_____

( ) Using equations and formulas

( ) Understanding geometric principles (angles, volume, area)

( ) Other

. What measuring instruments or devices are used in this occupational area?
(Examples: ruler, micrometer, voltmeter)

. What actual on-the-job applications of math skills in this occupational area should be emphasized during the teaching of this course?
(Examples: measuring wire, computing sales tax, calculating bills of materials)

4. What specific reading skills should be emphasized during the teaching of this course?

( ) Understanding written directions
( ) Reading charts and schematic drawings
( ) Identifying and interpreting specific details
( ) Determining meanings of unfamiliar technical terms
( ) Understanding trade abbreviations and symbols
( ) Other

____

____

5. What teaching strategies for improving reading comprehension skills could be incorporated into the teaching of this course?

( ) Use of textbook
( ) Use of job sheets
( ) Other
( ) Use of information sheets
( ) Use of newspapers and trade journals
( ) Use of manufacturer's specifications

____

____

____

6. What actual on-the-job applications of reading and communication (written and oral) skills in this occupational area should be emphasized during the teaching of this course?

( ) Reading manuals
( ) Using standard references
( ) Writing orders
( ) Talking to customers
( ) Other
( ) Writing complete sentences
( ) Using correct punctuation
( ) Capitalizing in abbreviations and sentences

____________________ ____________________

____________________ ____________________

____________________ ____________________

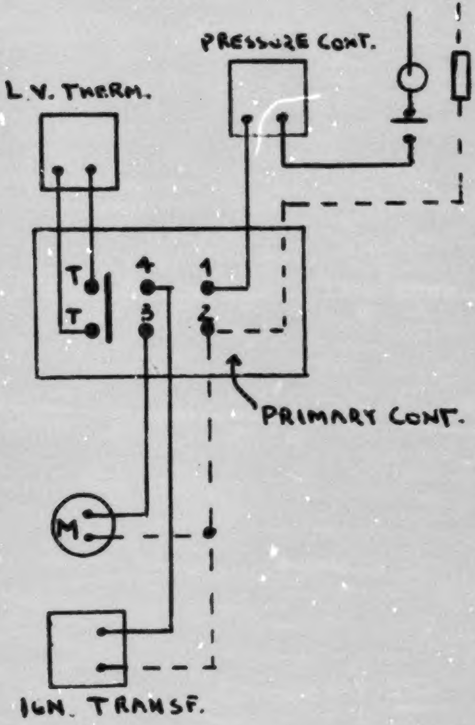
Unit I: Energy Conservation Wiring

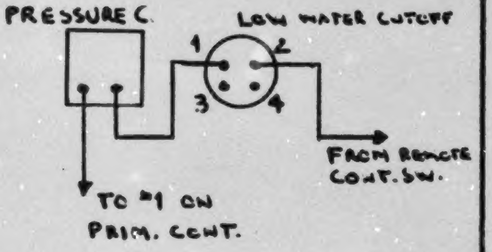
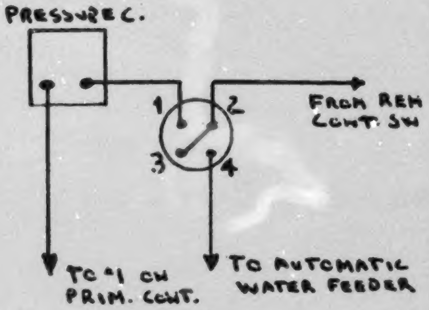
Level Three: Motors and Controls
Suggested Time: *100 Hours / 150 Periods*

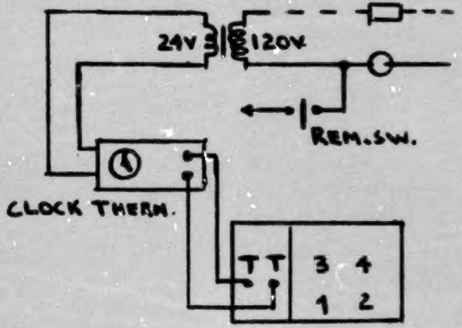
Performance Objectives

Upon completion of this unit the student will be able to:

- Wire an oil fired basic steam system with a low voltage thermostat.
- Wire an oil fired basic system using a clock thermostat and transformer.
- Wire an oil fired deluxe steam system using all the equipment.
- Wire a gas fired integrated warm air heating system.
- Wire a gas fired integrated hot water heating system.

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
1. Wire an oil-fired basic steam system, which includes a low-voltage thermostat, pressure control, aquastat and primary control  PRESSURE CONT. L.V. THERM. T T 4 3 1 2 PRIMARY CONT. M IGN. TRANSF. Fig. #1	A. Display the controls of the basic steam system, and briefly describe their operation in the circuit B. Demonstrate 1. Mounting of all equipment a. Low voltage thermostat b. Pressure control c. Aquastat d. Primary relay control e. Circuit breaker panel f. Remote emergency switch g. Oil burner 2. Wiring of all components in circuit (Fig. #1) 3. Testing circuit for correct operation a. Turn on remote control b. Place thermostat above room temperature c. Relay should energize burner fire	A. Discuss heating systems 1. Three types 2. Characteristics of each type 3. Basic principle of operation of each type 4. Comparison of three types B. Discuss types of fuel used for heating systems 1. Oil 2. Gas

2. Wire an oil-fired basic steam system per task #1; add a low water cutoff  PRESSURE C. LOW WATER CUTOFF 1 2 3 4 FROM REMOTE CONT. SW. TO #1 ON PRIM. CONT. Fig. #2	A. Display the low-water cutoff; describe its function, and demonstrate its operation in the circuit B. Review demonstration of mounting of equipment 1. Mount low water cutoff Stress that device must be mounted level for proper operation C. Wire equipment including low water cutoff (Fig. #2) D. Test job for proper operation 1. Follow procedure per task #1 2. Test functioning of low water cutoff by operating float	A. Discuss the low water cutoff 1. Function 2. Construction 3. Principle of operation 4. Circuitry 5. Types B. Discuss steam heating systems 1. How steam is produced 2. Typical piping layout of a one-pipe steam system
3. Wire an oil-fired basic steam system per Task #1; add a low water cutoff and an automatic water feeder (electrical or mechanical)  PRESSURE C. 1 2 3 4 FROM REM CONT. SW TO #1 ON PRIM. CONT. TO AUTOMATIC WATER FEEDER Fig. #3	A. Display electric valve and mechanical water feeder, describe their construction and demonstrate their operation in the circuit (Fig. #3) B. Review mounting of equipment 1. Install electric valve C. Review job wiring procedure D. Test job for proper operation 1. Operate float of low water cutoff to check operation of electric valve and cutoff E. Remove low water cutoff and electric valve from system F. Install combination low water cutoff mechanical water feeder G. Test job for correct operation 1. Operate float on cutoff to check operation of mechanical feeder and cutoff	A. Discuss types of water feeders 1. Low water cutoff with electric valve a. Construction and operation b. Circuitry with low water cutoff 2. Low water cutoff with mechanical water feeder a. Construction and operation b. Operation from low water cutout float

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
4. Wire an oil-fired basic system (as in Job #1), using a clock thermostat and transformer  Fig. #4	A. Display a clock thermostat, describe its construction, and demonstrate its operation in the circuit B. Display the clock transformer and describe its purpose C. Review mounting of equipment 1. Install clock thermostat with transformer D. Review job wiring procedures 1. Wire clock thermostat, including transformer (Fig. #4) Caution: Transformer must be wired in uninterrupted circuit E. Test for correct operation of all circuit components 1. Operate clock manually to check for correct operation	A. Discuss thermostats 1. Basic principle of operation 2. Switching arrangements of all types 3. Voltage of all types B. Discuss clock thermostats 1. Principle of operation 2. Function of clock relative to thermostat 3. Electric and battery operated 4. Setting of on and off periods

5. Wire an oil-fired deluxe steam system, using all the equipment in Tasks #1 - #4

A. Review the steam heating system, including the construction and operation of all components
B. Mount all equipment comprising the controls for a deluxe steam heating system
    1. Circuit breaker
    2. Remote emergency switch
    3. Primary relay
    4. Pressure control
    5. Low water cutoff
    6. Electric water valve
    7. Aquastat
    8. Clock
    9. Thermostat
    10. Transformer
C. Perform job wiring of the deluxe system
D. Test for correct operation
    1. Thermostat
    2. Low water cutoff
    3. Remote switch

A. Discuss pressure controls
    1. Function
    2. Types
    3. Operation in circuits
B. Discuss aquastats
    1. Function
    2. Types
    3. Operation in circuits
C. Discuss primary relay controls (Fig. #5) - RA817A Stack Relay)
    1. Function
    2. Types
    3. Operation

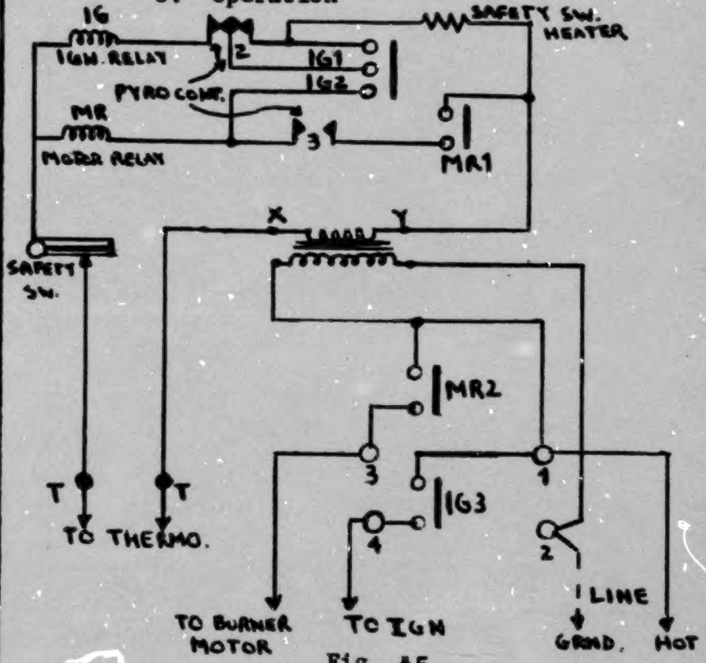
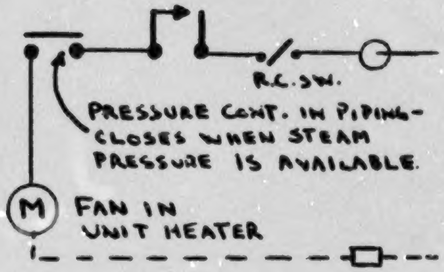

IG
IGN. RELAY
2
IG1
IG2
SAFETY SW.
HEATER
PYRO CONT.
MR
MOTOR RELAY
3
MR1
X
Y
SAFETY SW.
MR2
T
T
TO THERMO.
3
1
IG3
4
2
LINE
TO BURNER MOTOR
TO IGN
GRND.
HOT

Fig. #5

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
6. Wire an oil-fired steam unit heater,using a line voltage thermostat and a reverse acting pressure control Note: This unit heater is installed in a steam system that maintains constant steam pressure . The fan operates when area thermostat calls for heat if piping is under adequate steam pressure  R.C.SW. PRESSURE CONT. IN PIPING-CLOSES WHEN STEAM PRESSURE IS AVAILABLE. M FAN IN UNIT HEATER Fig. #6	A. Display a steam unit heater and describe its function B. Display the reverse action pressure control and demonstrate its operation C. Demonstrate mounting of equipment D. Perform job wiring E. Test for correct operation 1. Both switches must close in order to energize unit heater	A. Discuss the function and operation of a unit heater B. Discuss the line voltage thermostat and compare with the low voltage type

7. Wire and connect an oil-fired steam unit heater per Task #6 adding a time clock	A. Display a time clock and demonstrate its operation in the circuit B. Explain that the clock portion must be an uninterrupted circuit C. Review mounting of equipment, with addition of time clock D. Perform job wiring, including the clock E. Test for correct operation of the unit heater from the three circuit controls	A. Discuss time clocks 1. Purpose 2. Construction 3. Principle of operation 4. Applications B. Discuss the reverse acting pressure control 1. Basic construction 2. Comparison with direct acting pressure control 3. Operation in a circuit

Tasks	TEACHING CONTENT Development of Skills	 Development of Related Information

8. Wire an electrically operated flue pipe damper to an existing oil-fired steam system	A. Display a damper, and demonstrate its operation
	B. Review mounting procedures for equipment used in the deluxe steam system
	C. Review job wiring for a deluxe steam system
	   1. Wire in the damper to primary control (Fig. #7)
	D. Test job for correct operation
	   1. Test entire deluxe steam system
	   2. Test damper which should be open with burner running and closed with burner off
		A. Discuss flue-pipe dampers
		   1. Relationship to high cost of fuel
		   2. Construction
		   3. Principle of operation
		   4. Application

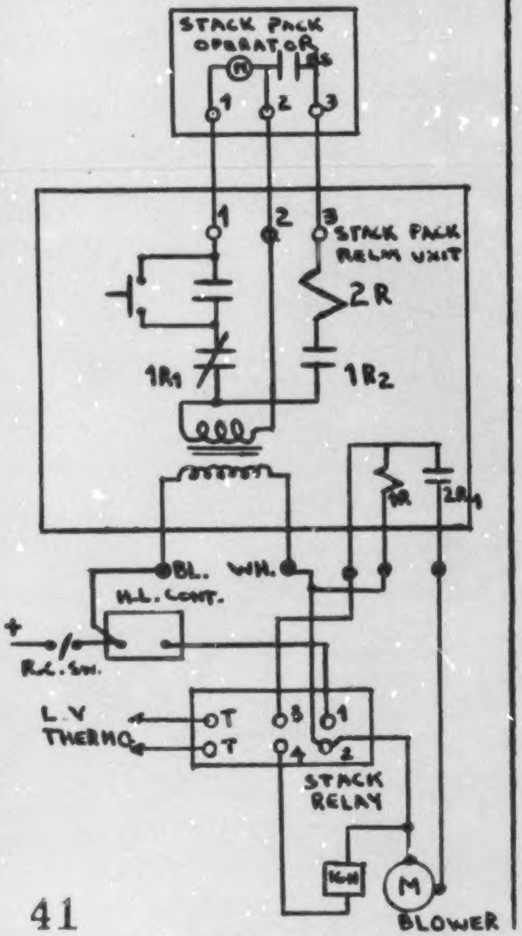

STACK PACK OPERATOR
1
2
3
STACK PACK RELAY UNIT
2R
1R1
1R2
1R
2R1
BL.
WH.
H.L. CONT.
+
R.C. SW.
L.V THERMO
T
T
3
1
4
2
STACK RELAY
IGN
M
BLOWER

Fig. #7

9. Wire the controls for an oil-fired gravity hot water system using a line voltage thermostat

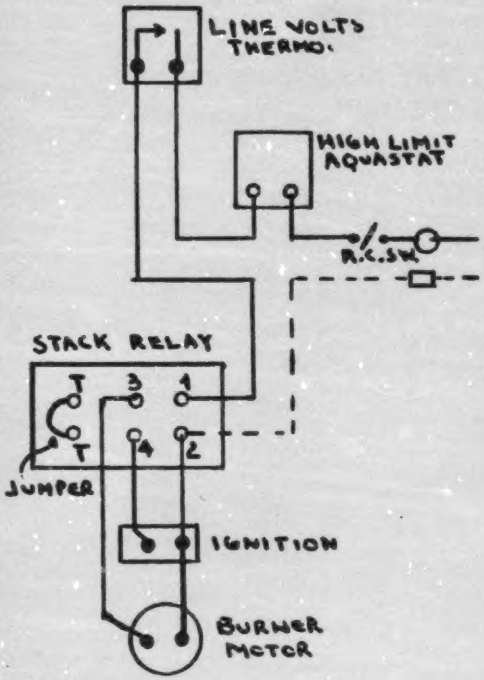
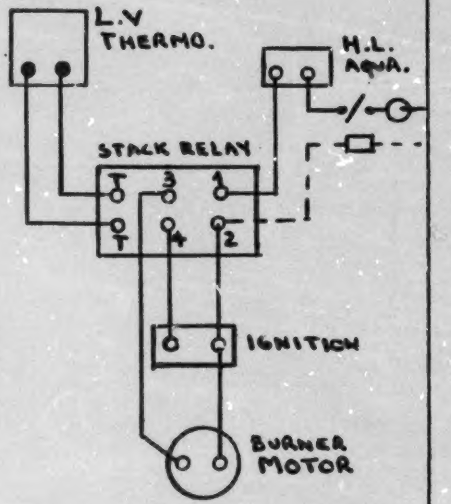

LINE VOLTS THERMO.
HIGH LIMIT AQUASTAT
R.C.SW
STACK RELAY
T
3
1
T
4
2
JUMPER
IGNITION
BURNER MOTOR

Fig. #8

A. Display the components needed for the job
    1. Line-voltage thermostat
    2. Aquastat (line voltage)
    3. Breaker panel
    4. Remote emergency switch
    5. Primary relay
    6. Oil burner
B. Demonstrate the operation of each component
C. Demonstrate mounting of all equipment
D. Demonstrate job wiring procedures
E. Test for correct operation from thermostat, aquastat, and emergency switch

A. Discuss the gravity hot water system
    1. Principle of operation
    2. Disadvantages
        a. Little control of heat
        b. Inability to provide domestic hot water in summer
    3. Develop typical piping layout of a gravity hot water system

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
10. Wire the controls for an oil-fired gravity hot water system,using a low voltage thermostat  L.V THERMO. H.L. AQUA. STACK RELAY T 3 1 T 4 2 IGNITION BURNER MOTOR Fig. #9	A. Display the low-voltage thermostat and demonstrate its operation B. Review installation of equipment used in previous job,substituting the low voltage thermostat for the line voltage type C. Review job wiring procedures Note wiring of low voltage thermostat (Fig. #9) D. Test for correct operation from thermostat and aquastat	A. Compare the low voltage thermostat to the line voltage-type 1. Advantage of more precise temperature control 2. Ease and economoy of wiring B. Compare the gravity hot water system to a steam system 1. Advantage: sustained heating 2. Disadvantage: uncontrolled heating

11. Wire the controls for an oil-fired forced hot water system, using a line voltage aquastat and thermostat

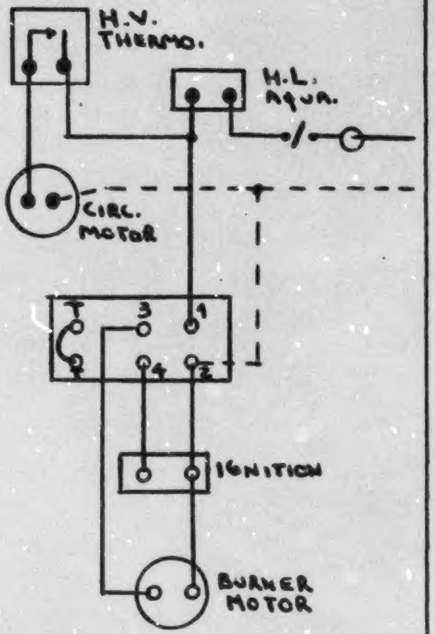


Fig. #10

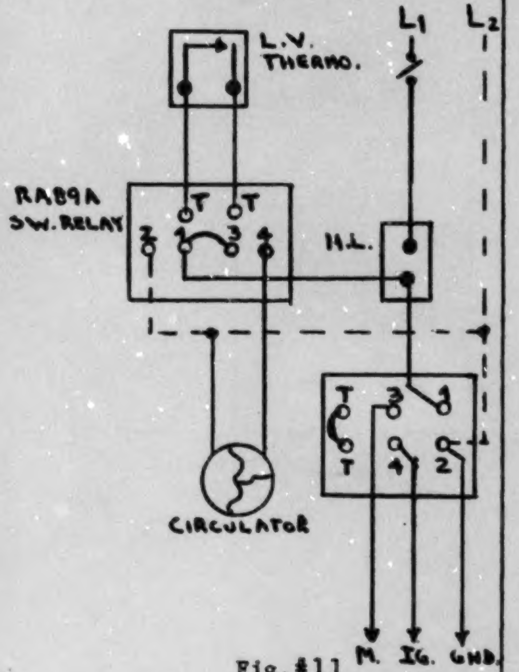
A. Display the controls used in this system, and demonstrate their operation

B. Demonstrate mounting of controls

C. Demonstrate wiring of the forced hot water system

D. Test job for correct operation
   1. Aquastat fires burner
   2. Thermostat operates circulator

A. Discuss the forced hot water heating system
   1. Definition
   2. Advantages over gravity system
      a. Control
      b. Economy
   3. Components and their functions
      a. Circulator
      b. Flow-control valve
      c. Thermostat
      d. Aquastat

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
12. Wire the controls for an oil-fired forced hot-water system, using a low-voltage thermostat and line-voltage aquastat  L₁ L₂ L.V. THERMO. RA89A SW. RELAY T T 2 1 3 4 H.L. CIRCULATOR T 3 1 T 4 2 M. IG. GND. Fig. #11	A. Display low-voltage thermostat and demonstrate operation B. Display switching relay; describe construction and operation in conjunction with the low voltage thermostat C. Review mounting of equipment D. Demonstrate wiring of low voltage thermostat with switching relay (Fig. #11) E. Test for correct operation 1. Thermostat operates line-voltage circulator through switching relay 2. Aquastat operates burner	A. Discuss and compare use of aquastats in hot water systems with steam systems B. Develop layout for piping of typical forced hot water heating system

13. Wire controls for an oil-fired forced hot water system, using two aquastats and a live voltage thermostat

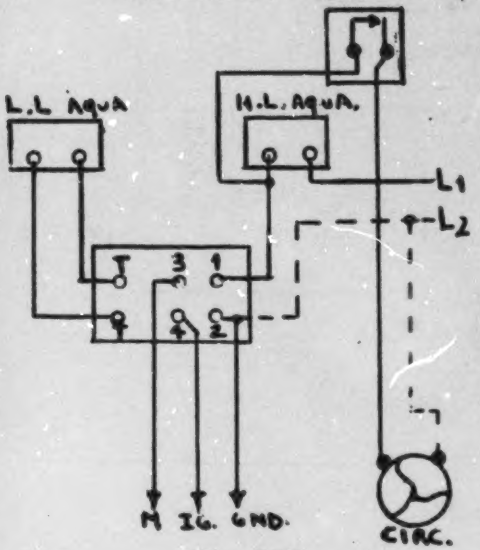


Fig. #12

A. Discuss fact that some aquastats are of similar construction but are wired into circuit in relation to the function of the circuit
B. Review mounting of equipment
C. Perform job wiring including both aquastats (Fig. #12)
D. Test for correct operation from aquastats for low limit and high limit safety

A. Discuss use of two aquastats in system, one to operate as a low limit and the other for high limit safety
B. Discuss operation of aquastats
    1. Construction
    2. Principle of operation
    3. Type of switch used

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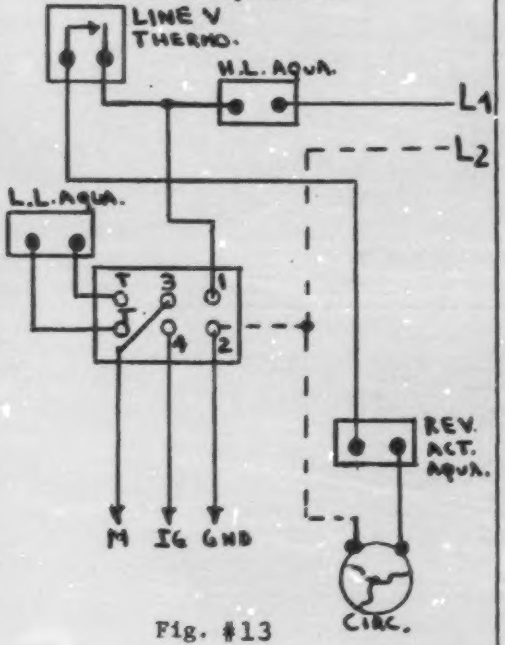
	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
14. Wire an oil-fired integrated forced hot water system, using a live voltage thermostat; provide for domestic hot water; use three aquastats  LINE V THERMO. H.L. AQUA. L1 L2 L.L. AQUA. T T 3 1 4 2 REV. ACT. AQUA. M IG GND CIRC. Fig. #13	A. Display reverse-acting aquastat, and describe its switching action B. Review mounting of equipment C. Review job wiring procedures; demonstrate wiring of the reverse-acting aquastat D. Test job for correct operation 1. Low limit 2. High limit 3. Operation of circulator	A. Discuss the use of an additional aquastat for domestic hot water 1. Low limit maintains domestic hot water and boiler water temperature 2. High limit provides safety for maximum water temperature 3. Reverse acting prevents cold water circulation to radiators

15. Wire an oil-fired integrated forced hot water system, using a low-voltage thermostat; provide for domestic hot water

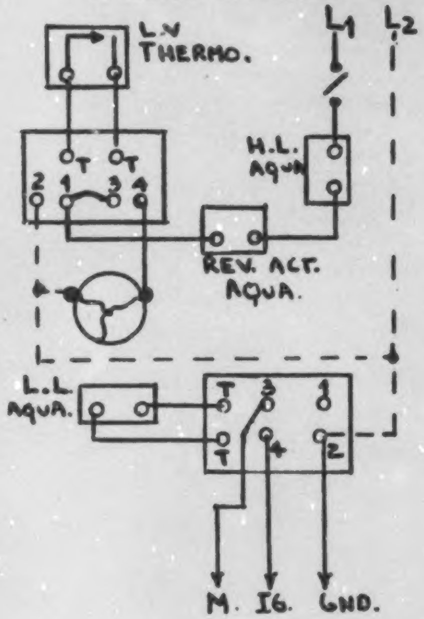
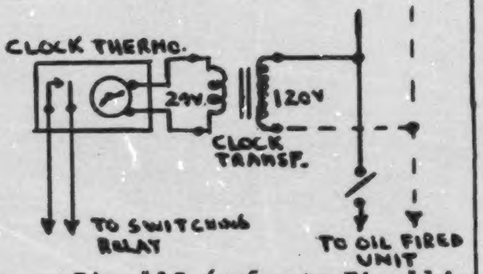
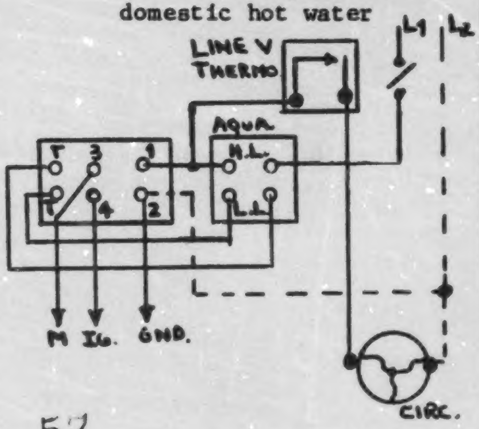

L.V THERMO.
L_1
L_2
T
T
2
1
3
4
H.L. AQUA
REV. ACT. AQUA.
L.L. AQUA.
T
3
1
T
4
2
M.
IG.
GND.

Fig. #14

A. Review the low-voltage thermostat in conduction with switching relay
B. Review installation of equipment
C. Review job wiring procedures
D. Test for correct operation of the three aquastats

A. Discuss preparation of fuel for combustion in an oil burner
   1. Atomization
      a. High pressure
      b. Low pressure
      c. Centrifugal
   2. Vaporization

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
16. Wire an oil-fired non-integrated, forced hot water system, using a clock thermostat; provide for domestic hot water  CLOCK THERMO. 24V. 120V CLOCK TRANSF. TO SWITCHING RELAY TO OIL FIRED UNIT Fig. #15 (refer to Fig. #14, Task #15)	A. Review construction and operation of the clock thermostat B. Review job mounting procedures C. Wire system including clock thermostat; note that clock transformer is uninterrupted (Fig. #15) D. Test for correct operation of the clock thermostat and the three aquastats	A. Discuss transformers 1. Definition 2. Types 3. Principle of operation 4. Applications 5. Working out examples for turns and voltage ratios
17. Wire an oil-fired non-integrated, forced hot water system, using a dual aquastat having high and low limits; provide for domestic hot water  L1 L2 LINE V THERMO AQUA. H.L. T 3 1 4 2 L.L. M IG. GND. CIRC. Fig. #16	A. Display the dual aquastat and demonstrate its operation B. Review job mounting procedure C. Review wiring of equipment D. Demonstrate how to connect the dual aquastat E. Test for correct operation	A. Discuss the dual aquastat 1. Construction 2. Advantage 3. Operation B. Discuss location of aquastats in relation to height of water in boiler

18. Wire an oil-fired non-integrated, forced hot water system, using a combination high limit and reverse acting aquastat; provide for domestic hot water

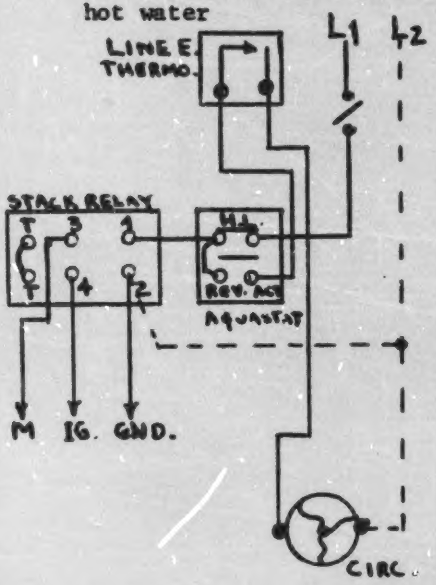


Fig. #17

A. Display the combination high limit and reverse-acting aquastat, and demonstrate its operation
B. Review mounting of equipment
C. Demonstrate job wiring, including connections for combination aquastat
D. Test for correct operation of combination aquastat and low-limit aquastat

A. Review non-integrated forced hot water system
    1. Principle of operation
    2. Circuits
    3. Equipment used
B. Discuss the combination high limit and reverse-acting aquastat
    1. Construction
    2. Advantage
    3. Circuitry

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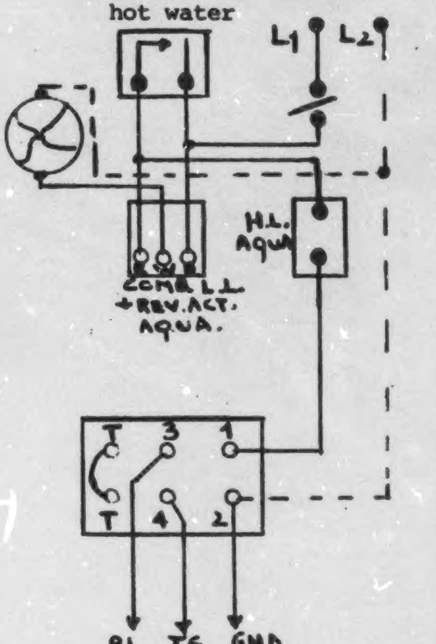
	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
19. Wire an oil-fired, integrated hot water system, using a line voltage thermostat; provide for domestic hot water  Fig. #18 NOTE: R.W. CLOSES ON TEMP. RISE R.B. CLOSES ON TEMP. DROP	A. Display the equipment used in the integrated hot water system; review construction and function of each piece of equipment; demonstrate operation of equipment B. Demonstrate mounting of equipment C. Demonstrate job wiring procedures for the system D. Test for correct operation 1. Circulator and burner operation from thermostat through L6006	A. Discuss the integrated hot water heating system 1. Compare this system to nonintegrated type 2. Retention of hot water for better heating and domestic use 3. Equipment used a. Combination L-6006 aquastat b. Circulator c. Primary control d. Remote emergency control e. Thermostat f. Highlight aquastat

20. Wire an oil-fired, integrated hot water system, using a low-voltage thermostat; provide for domestic hot water

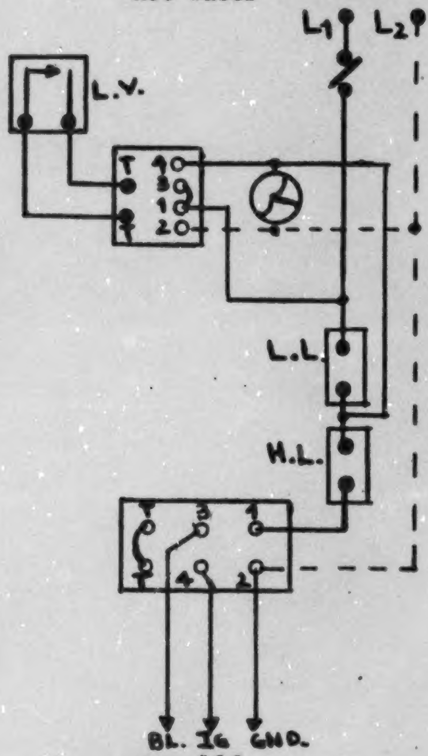


Fig. #19

A. Review the advantage of the low-voltage thermostat
B. Demonstrate mounting of equipment
C. Review job wiring procedures
D. Test for correct operation
    1. L6006 for low limit and reverse action for circulator
    2. Aquastat for high limit
    3. Thermostatic operation of burner and circulator simultaneously

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A. Discuss fuel waste due to high temperature settings (Fig. #20)
B. Discuss the combination L6006 aquastat
    1. Construction-two aquastat units built into one switch
    2. Applications
    3. Circuitry

FUEL WASTE DUE TO HIGH THERMOSTAT SETTINGS

Average Yearly Requirements, gallons at 70° F	Oil Wasted Yearly (gallons) at Thermostat Settings At 75°	At 80°
1.500	214	428
2.000	286	572
2,500	357	714
3,000	428	856
3,500	500	1000
4.000	571	1142
5,000	714	1428
10,000	1428	2856
15,000	2143	4286

Fig. #20

TEACHING CONTENT

Tasks	Development of Skills	Development of Related Information
21. Wire an oil-fired, hot water system, using a combination switching relay with a dual-action action aquastat	A. Display the combination switching relay, describe its application and demonstrate its operation B. Review mounting of equipment C. Review job wiring procedure, including wiring of combination relay D. Test job for correct operation 1. Thermostatic operation of burner and circulator simultaneously 2. Operation of low-limit and reverse-acting aquastat 3. Operation of high-limit aquastat	A. Discuss the combination switching relay with dual aquastat 1. Construction 2. Operation 3. Circuitry 4. Disadvantage B. Discuss fuel waste due to high temperature settings during the night (Fig. #22)

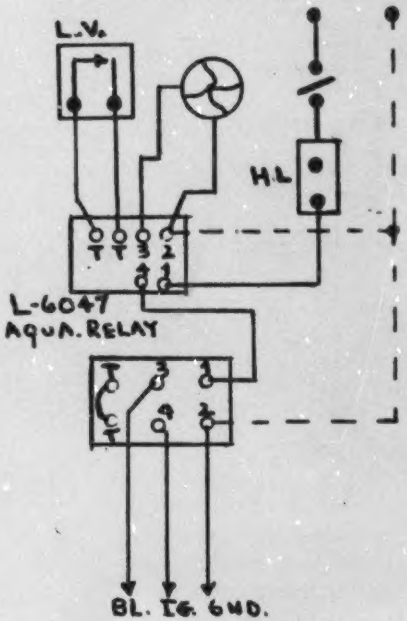

Fig. #21

FUEL WASTE DUE TO HIGH NIGHT SETTINGS

Lowered Night Temperature degrees F	Savings in Oil (per cent) when Temperature Is Lowered at Night for 4 hours	8 hours	12 hours	16 hours
70	0	0	0	0
65	2.5	5	7.5	9.5
60	5	9.5	14.5	19.5
55	7.5	14.5	21.5	28.5
50	9.5	19.5	28.5	38.5

Fig. #22

22. Wire an oil-fired zoned, integrated forced hot water heating system; provide for domestic hot water with two zone values, using two low-voltage thermostats and one circulator	A. Display the zone valve, and demonstrate its operation B. Demonstrate installation of equipment, including zone valves C. Demonstrate job wiring, including zone valves D. Test job for correct operation 1. Operation of each zone valve from its thermostat 2. Operation of circulator from either thermostat	A. Discuss zoning in heating systems 1. Definition 2. Advantages 3. Disadvantage B. Discuss the zone valve 1. Construction 2. Operation 3. Installation
23. Wire an oil-fired, zoned, integrated, forced hot water heating system with two low-voltage thermostats and two circulators; use an aquastat switching relay for zoning	A. Display the triple-acting aquastat, and demonstrate its operation B. Review mounting of equipment, including the triple-acting aquastat C. Review job wiring, including connections to triple-acting aquastat D. Test job for correct operation 1. Each thermostat operates its own circulator and burner 2. Triple-acting aquastat provides high level, low level and reverse action	A. Discuss zoning, and develop a typical piping layout for two zone operation B. Discuss the triple-acting aquastat with switching relay 1. Construction 2. Operation 3. Circuitry

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
24. Wire an oil-fired, integrated forced hot water system; provide for domestic hot water; install a low-voltage thermostat and a flue pipe damper	A. Display the damper, and demonstrate its operation B. Review installation of the flue pipe damper C. Review the job wiring procedures D. Test job for correct operation 1. Operation of flue damper 2. Operation of thermostat and aquastats used	A. Review flue pipe dampers 1. Construction 2. Purpose 3. Operation 4. Circuitry B. Review the integrated hot water system and all its components
25. Wire the controls for an oil-fired gravity warm air heating system	A. Display components used on system, and demonstrate operation of each component B. Demonstrate mounting of all equipment C. Demonstrate job wiring procedures and connections of all equipment D. Test job for correct operation 1. Operation of airstat to operate burner 2. Operation of thermostat	A. Discuss the basic gravity, warm air heating system 1. Compare warm air system to steam and hot water systems 2. Advantages and disadvantages of warm air systems 3. Advantages and disadvantages of gravity warm air system B. Discuss components used on gravity warm air system 1. Airstat 2. Thermostat 3. Primary control 4. Burner 5. Remote emergency switch

26. Wire an oil-fired, integrated, forced warm air heating system with a high limit and a fan control	A. Display reverse-acting airstat, and demonstrate its operation B. Demonstrate mounting of equipment C. Demonstrate wiring of equipment D. Test job for correct operation 1. Direct-acting airstat for burner operation 2. Reverse-acting airstat for fan operation 3. Thermostat for burner operation	A. Discuss the nonintegrated, forced warm air heating system 1. Compare to gravity type 2. Compare to integrated type B. Develop a layout showing location of warm air controls in a duct system C. Discuss components required in the nonintegrated system 1. Fan 2. Direct-acting airstat 3. Reverse-acting airstat 4. Primary control 5. Low voltage thermostat 6. Burner 7. Remote emergency switch

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
27. Wire the controls for an oil-fired, integrated forced warm air heating system with a combination control	A. Display equipment used on system, and demonstrate operation of all equipment B. Demonstrate mounting of all equipment C. Demonstrate job wiring procedures for equipment D. Test job for correct operation 1. Thermostatic control of fan and burner 2. Operation of combination control for fan and burner	A. Discuss the integrated forced warm air heating system 1. Compare to non-integrated type 2. Components a. Fan b. Combination fan limit control c. Switching relay d. Low voltage thermostat e. Primary control f. Burner g. Remote emergency switch

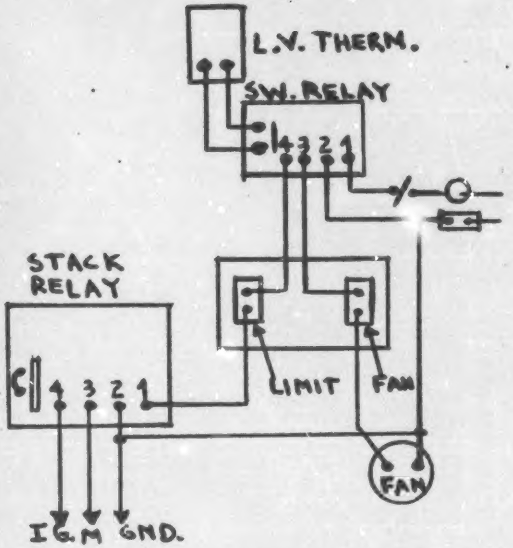

Fig. #23

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28. Wire the controls for an oil-fired, integrated, forced warm air heating system, using a duct zone valve

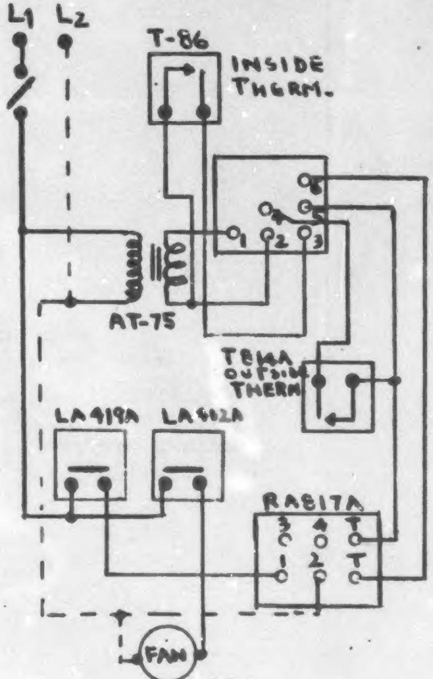
L1
L2
T-86
INSIDE THERM.
1
2
3
4
5
6
AT-75
TE4A OUTSIDE THERM
LA419A
LA412A
RA81TA
3
4
T
1
2
T
FAN

Fig. #24

A. Display equipment to be used, and demonstrate operation
B. Demonstrate mounting of equipment
C. Demonstrate wiring of equipment
D. Test job for correct operation
    1. Inside thermostatic operation of zone valve and burner
    2. Airstat and fan control of burner and fan

A. Review zone heating
    1. Advantages
    2. Function
B. Discuss components used
    1. Step-down transformer
    2. Zone valve
    3. Airstat
    4. Fan control
    5. Fan
    6. Outside thermostat
    7. Primary control
    8. Thermostat
    9. Burner
    10. Remote emergency switch

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
29. Wire an electrically operated flue-pipe damper in an existing oil-fired, integrated, forced air heating system. Refer to Fig. #23 Task #27 for the equipment to be used	A. Review mounting of equipment B. Review job wiring procedures C. Demonstrate wiring of the damper D. Test job for correct operation 1. From damper 2. From controls	A. Review the flue pipe damper as to construction, operation and circuitry B. Review warm air heating systems 1. Types 2. Advantages and disadvantages 3. Components 4. Circuit types used

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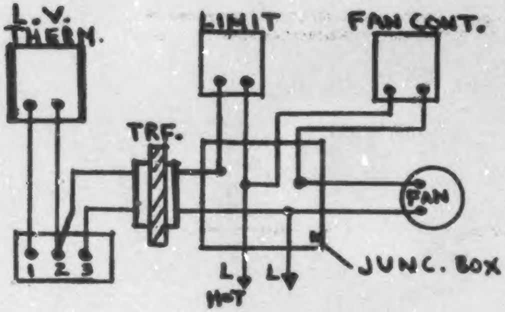
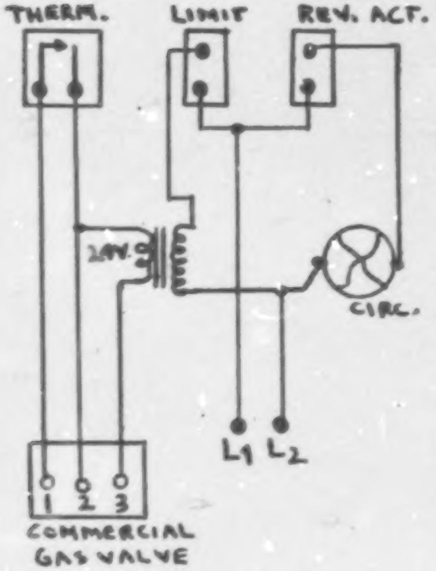
30. Wire a gas-fired, integrated warm air heating system	A. Display gas valve, and demonstrate operation B. Demonstrate mounting of equipment C. Demonstrate wiring of high-volt and low-volt sides (Fig.#25) D. Test job for correct operation 1. Thermostat to operate gas valve and fan motor 2. Limit switch to operate burner 3. Fan control to operate fan	A. Discuss gas heating 1. Advantages 2. Disadvantages B. Discuss the gas valve 1. Construction 2. Operation 3. Circuitry



Typical Wiring Diagram for L4040 with a Gas Valve (Three Terminal-One Common) In a Forced Warm Air Heating System

Fig. #25

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information

31. Wire a gas-fired, integrated, hot water heating system; provide for domestic hot water

 THERM.
LIMIT
REV. ACT.
24V.
CIRC.
L1
L2
1
2
3
COMMERCIAL GAS VALVE
Fig. #26
	1. Review the construction and operation of a gas valve
	2. Review mounting of equipment
	3. Demonstrate job wiring procedure
	4. Test for correct operation
	    1. Thermostatic operation of burner and circulator
	    2. Circulator and burner control from both aquastats
		A. Review hot water heating systems
		    1. Types
		    2. Advantages and disadvantages
		    3. Components
		    4. Systems circuitry

32. Wire a gas-fired steam heating system with a low water cutoff, a pressure control, and an aquastat for domestic hot water

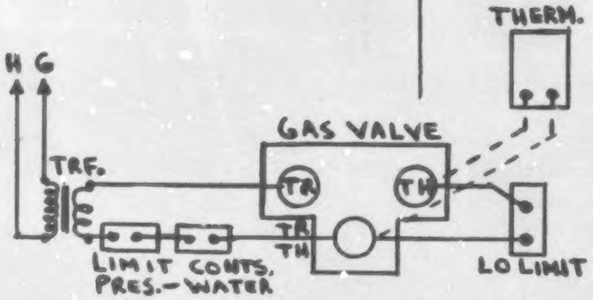

THERM.
H
G
TRF.
GAS VALVE
TR
TH
TR
TH
LIMIT CONTS.
PRES.-WATER
LO LIMIT

Fig. #27

A. Review construction and operation of the gas valve
B. Review mounting of equipment
C. Demonstrate job wiring procedures (Fig. #27)
D. Test for correct operation
    1. Thermostatic control of burner
    2. Aquastat, pressure control and low water cut-off

A. Review steam heating systems
    1. Types
    2. Advantages and disadvantages
    3. Components
    4. Systems circuitry

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
33. Wire an oil-fired steam heating system providing domestic hot water, using a primary control, operated by a cell flame sensor	A. Display the CAD cell-flame sensor, and demonstrate its operation B. Display the primary control and demonstrate its operation C. Review mounting of equipment D. Demonstrate job wiring procedure E. Test job for correct operation 1. Operation of primary control from sensor 2. Checking out of all controls	A. Discuss the flame sensor 1. Construction 2. Operation 3. Circuitry 4. Testing B. Discuss the primary control (CAD cell type) 1. Construction 2. Operation 3. Circuitry

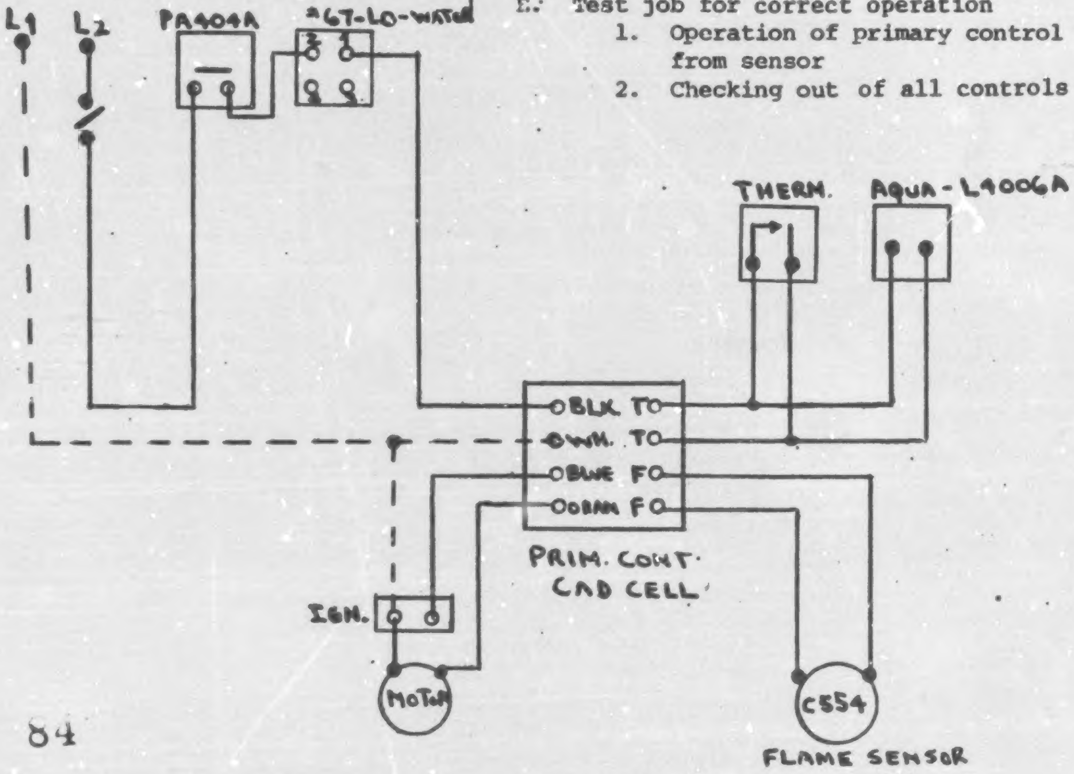

L1
L2
PA404A
*67-LO-WATER
THERM.
AQUA-L4006A
BLK. TO
WH. TO
BLUE FO
ORAN FO
PRIM. CONT.
CAD CELL
IGN.
MOTOR
C554
FLAME SENSOR

Fig. #28

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34. Wire an oil-fired steam heating system, using an electronic primary control with photocell

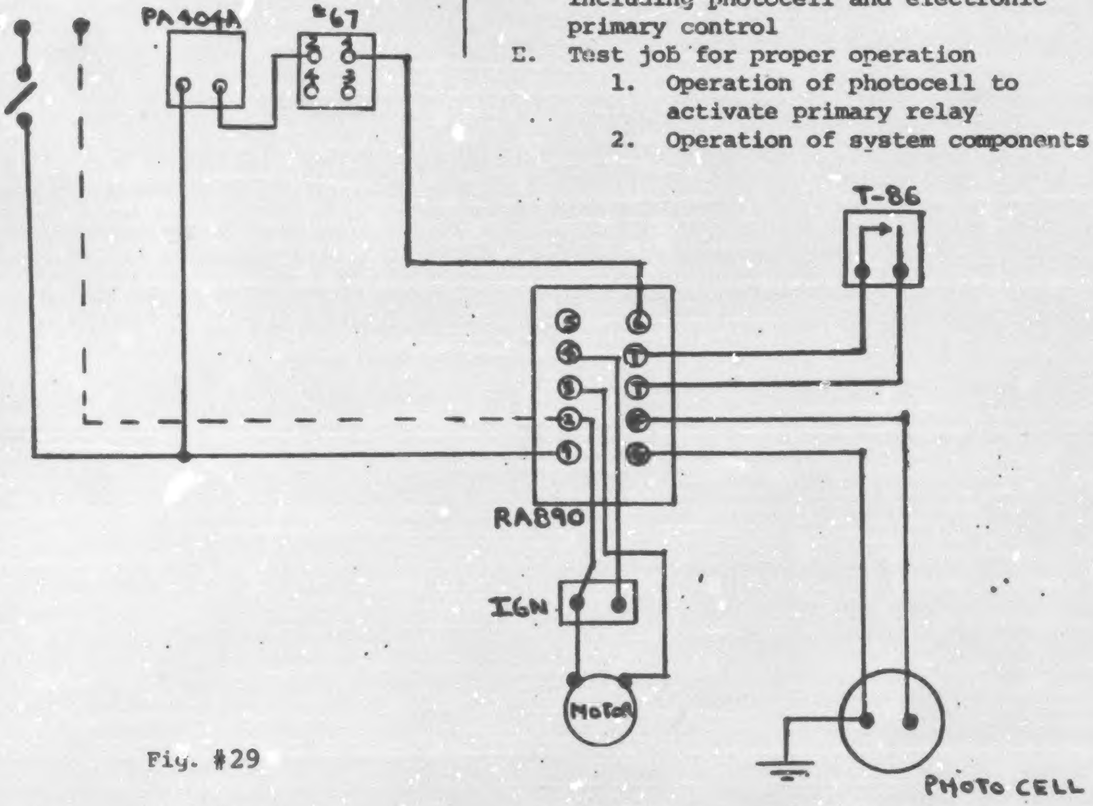


Fig. #29

A. Display the electronic primary control and demonstrate its operation
B. Display the photocell and describe its operation
C. Review mounting of equipment
D. Demonstrate wiring procedures, including photocell and electronic primary control
E. Test job for proper operation
    1. Operation of photocell to activate primary relay
    2. Operation of system components

A. Discuss the electronic primary control
    1. Construction
    2. Operation
    3. Circuitry
    4. Testing
B. Discuss the photocell construction and operation
C. Review of Unit I-Heating Systems

Unit II: D.C. Motor Repair and Rewinding

Level Three: Motors and Controls
Suggested Time: *100 Hours / 150 Periods*

Performance Objectives

Upon completion of this unit the student will be able to:

- Dismantle a D.C. motor - reassemble and test.
- Strip, clean, test, and prepare a commutator for rewinding.
- Completely overhaul a D.C. motor using all the equipment.
- Trouble shoot D.C. motors for motor failure, motor noise, and overheated motor.

Tasks	Development of Skills	Development of Related Information
1. Dismantle a D.C. motor	Demonstrate 1. Taking nameplate data and recording in card file 2. Removing pulley from motor shaft 3. Center-punching endshields and frame for reassembling purposes 4. Removing brushes, brush caps, key 5. Removing bolts and end shields. 6. Removing armature and placing it on a stand 7. Preliminary checking of parts to determine repairs required	A. Discuss the D.C. motor 1. Definition 2. Characteristics 3. Advantages and disadvantages 4. Construction 5. Principle of operation B. Discuss basic hand tools 1. Hammers: hard-face and soft-face 2. Center punch 3. Wrenches a. Open end b. Box c. Ratchet d. Spin tights C. Describe and demonstrate safety in handling of motors and tools
2. Reassemble and test a D.C. motor	A. Discuss need to check all parts for good working order before reassembly is performed. B. Demonstrate: 1. Installing armature in frame 2. Installing end shields and fastening them to frame 3. Installing and seating in brushes 4. Checking spring tension 5. Making ground test 6. Checking for free turning and excessive end play of armature 7. Running motor and checking speed 8. Resetting of neutral, if necessary 9. Checking motor under load conditions	A. Discuss bearings used on D.C. motors 1. Sleeve and ball 2. Applications of each 3. Maintenance of each B. Discuss the magnetic circuit in a D.C. motor 1. Describe frame, shields, armature and field cores 2. Construction of each part 3. Function of each part C. Describe and demonstrate safety in reassembling D.C. motors

3. Record data for rewinding an armature

A. Discuss importance of taking correct data and give examples of consequences of errors. (Fig. #1).

B. Display a typical card used for recording data and describe purpose for each item included.

C. Demonstrate
   1. Counting the core slots
   2. Counting the commutator bars
   3. Determining coils per slot (bars ÷ slots)
   4. Measuring wire size with wire gauge or micrometer
   5. Determining coil pitch
   6. Determining type of winding and number of circuits
   7. Determining lead swing
   8. Counting number of turns in each coil
   9. Checking insulation type on the wire
   10. Checking the progress direction of the winding
   11. Measuring distance that winding extends beyond core

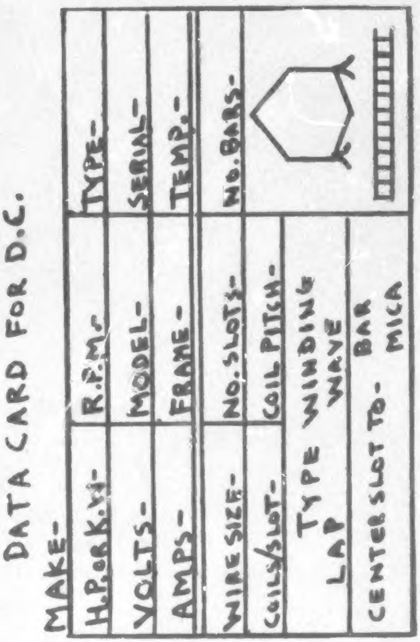
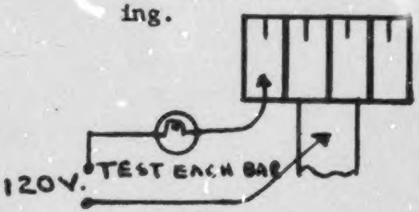
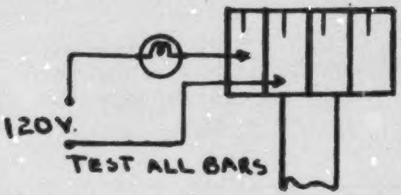
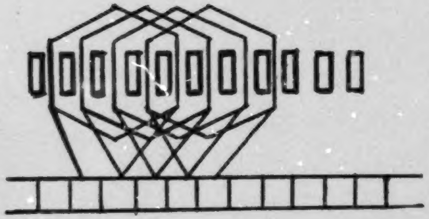

DATA CARD FOR D.C.
MAKE-
H.P.orK.W.-
R.P.M.-
TYPE-
VOLTS-
MODEL-
SERIAL-
AMPS-
FRAME-
TEMP.-
WIRE SIZE-
NO. SLOTS-
NO. BARS-
COILS/SLOT-
COIL PITCH-
TYPE WINDING
LAP
WAVE
CENTER SLOT TO-
BAR
MICA

Fig. 1

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
4. Strip and clean an armature	A. Discuss importance of stripping and cleaning a core properly B. Display problems that result from work C. Describe how armatures are heated to loosen wires for stripping D. Demonstrate 1. Removing wedges 2. Removing leads from commutator 3. Removing old coils from slots 4. Removing old slot insulation 5. Straightening core slots, if necessary 6. Removing burrs from all areas, if necessary	A. Describe the micrometer 1. Construction 2. Method of reading 3. Application in motor work 4. Method of checking several sizes of wire and motor shafts B. Discuss and compare stripping tools 1. Wedge driver 2. Heavy hacksaw blade 3. Diagonals 4. Files C. Describe and demonstrate safety practices in stripping and cleaning

5. Test and prepare a commutator for rewinding.  Fig. #2  Fig. #3	A. Discuss the importance of preparing a commutator correctly. B. Demonstrate 1. Cleaning out mica insulator with hacksaw blade 2. Sanding commutator with sand paper 3. Performing ground test (Fig. #2) 4. Making bar-to-bar test to locate shorts (Fig. #3) 5. Cutting risers with a hacksaw 6. Checking width and depth of cut in risers to accommodate wires	A. Discuss the electric circuit in a motor 1. Armature windings 2. Field windings 3. Brushes 4. Commutator a. Purpose b. Types c. Construction d. Maintenance e. Repair
6. Prepare and insulate an armature core for rewinding.	A. Discuss importance of proper preparation of core for rewinding B. Demonstrate 1. Checking on removal of old insulation paper 2. Straightening and tightening laminations 3. Removing burrs with a file 4. Cutting and installing core end insulators 5. Insulating shaft on both sides of core 6. Cutting, forming and installing slot insulation	A. Discuss slot insulations 1. Types 2. Thicknesses 3. Applications B. Discuss shaft insulations 1. Types 2. Applications C. Discuss tools used in preparing an armature core 1. Paper cutter 2. Insulation former 3. Scissors 4. Compass 5. Micrometer 6. Screwdriver D. Discuss and demonstrate safety in handling tools used in preparing a core

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
7. Rewind a lap type D.C. armature, using heavy wire method.  A lap winding of one coil per slot after the end leads are placed in the commutator bars Fig. #4	A. Review the armature data card and explain need to keep data items in mind when rewinding B. Demonstrate 1. Winding in first coil using proper pitch (Fig. #4) 2. Laying in bottom lead in commutator after scraping, leaving top lead out 3. Winding second coil in slot; laying in bottom lead and leaving out top. 4. Proceeding to second slot, progressing right 5. Winding in all coils; laying in bottom lead and leaving out top lead of each coil	A. Describe lap winding 1. Purpose 2. Circuitry 3. Method of recognition B. Discuss methods of winding armatures 1. Heavy wire method 2. Loop method 3. Two in hand method
8. Set leads in a commutator.	A. Demonstrate 1. Installing layer of insulation over bottom armature leads 2. Ringing out top lead of each coil with test set 3. Setting top lead of each coil in commutator one bar to right of bottom lead; scraping and installing each lead 4. Tying cord around leads in back of commutator 5. Cutting off excessive wire extending from risers	A. Discuss problems resulting from incorrectly connected armatures 1. Grounds 2. Opens 3. Shorts 4. Reverses 5. Incorrect motor operation B. Discuss the D.C. series motor 1. Connection 2. Characteristics 3. Applications 4. Hazardous feature

9. Make preliminary tests	A. Demonstrte the preliminary tests made on small armatures 1. Ground test 2. Short test on growler B. Describe the preliminary tests made on large armatures 1. Ground test 2. Short test 3. Bar-to-bar test	A. Discuss the D.C. shunt motor 1. Connection 2. Construction 3. Characteristics 4. Applications B. Discuss the need for preliminary testing of small-size and large-size armatures C. Explain necessity for extensive testing on large armatures
10. Solder a commutator to armature leads	A. Discuss problems that may result from poor soldering of a commutator. 1. Shorts between bars 2. Open circuits 3. Connections open under load B. Demonstrate 1. Placing of commutator in stand at angle so solder flows toward front 2. Selecting proper iron size and preparing tip 3. Applying flux to risers 4. Applying hot iron to bars one at a time 5. Applying solder to heated bar 6. Soldering the entire commutator 7. Removal of flux with alcohol 8. Removal of tie cord behind commutator	A. Discuss soldering methods 1. Types of guns and irons 2. Iron size related to armature size 3. Types of solder 4. Soldering flux 5. Use of alcohol after soldering 6. Safety practices when soldering leads or removing soldered leads

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information

11. Locate and repair grounds in an armature

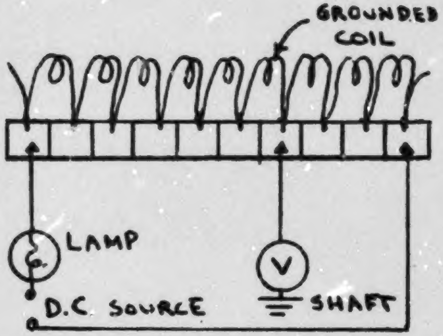



Fig. #5
	A. Discuss the meaning and effect of a fault ground on an armature
	B. Demonstrate preliminary test with series test lamp
	C. Describe how a visual test is made to locate a ground
	   1. Torn insulation
	   2. Short or shifted insulation
	   3. Wire wound outside of insulation
	   4. Solder to ground on commutator
	D. Demonstrate bar-to-bar test for ground using voltmeter method (Fig. #5)
		A. Discuss the meaning and importance of each item on a D.C. motor nameplate
		B. Discuss the millivoltmeter
		   1. Construction
		   2. Principle of operation
		   3. Applications

12. Locate and repair shorts in an armature

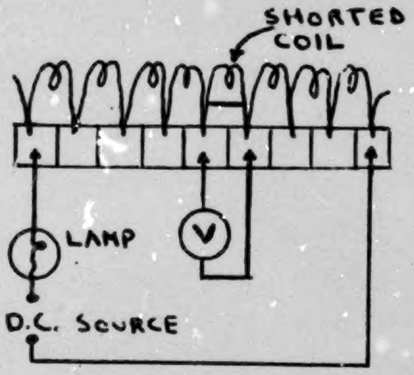
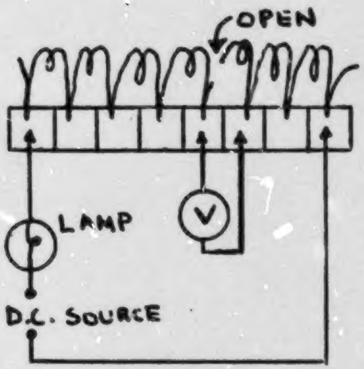


Fig. #6

A. Discuss the effect of shorted coil(s) on a D.C. motor
B. Demonstrate
   1. Sort test, using a growler and hacksaw blade
   2. Visual test to attempt to locate short
   3. Bar-to-bar test for locating shorts, using voltmeter method (Fig. #6)

A. Discuss armature shorts
   1. Definition
   2. Causes
      a. Excessive pounding of winding
      b. Carelessness when winding or soldering
   3. Types
      a. Two turns of one coil making electrical contact
      b. One coil making electrical contact with adjacent coil.
      c. Leads touching behind commutator risers
      d. Solder fallen between commutator bars
B. Describe the growler
   1. Construction
   2. Principle of operation
   3. Applications

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
13. Locate and repair opens in an armature  Fig. #7	A. Demonstrate the bar-to-bar test for locating opens (Fig. #7) B. Demonstrate a visual test for attempting to locate an open C. Discuss conditions under which an open coil may be jumped out and illustrate how this is done	A. Discuss the D.C. Compound motor 1. Types 2. Connections 3. Characteristics 4. Applications B. Discuss armature opens 1. Cause a. Poor connection at commutator b. Broken wire in coil 2. Effect a. Sparking at brushes b. Reduced torque

14. Locate and repair reversed coils in an armature

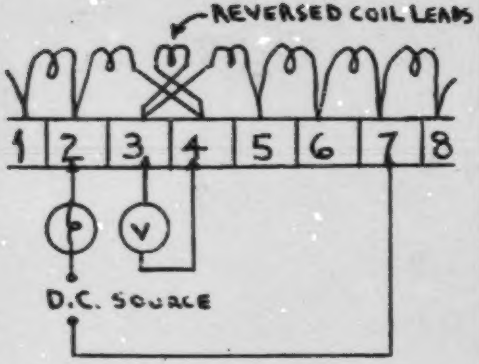


Fig. #8

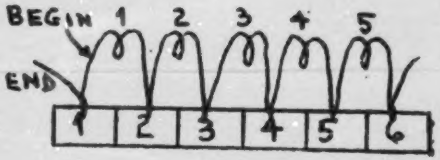
A. Discuss single test procedure for shorts, opens, and reverses

B. Demonstrate bar-to-bar test for reversed coils (Fig. #8)

C. Demonstrate compass test for reversed coil.
   1. Application of D.C. to commutator
   2. Slow rotation of armature, holding compass near each coil as it passes
   3. Compass reversal at point of coil reversal

A. Discuss armature reaction
   1. Cause
   2. Effect
   3. How it is corrected in interpole and noninterpole motors
   4. Connection of interpoles into circuit.

B. Discuss armature reverses
   1. Cause: Placing of leads in wrong commutator bars.
   2. Effect: Bucking polarity of reversed coil with eventual coil burn out

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
15. Lap wind a D.C. armature by the loop method.  BEGIN 1 2 3 4 5 END 1 2 3 4 5 6 Fig. #9	A. Discuss and compare the loop method with the heavy wire method B. Review taking data, stripping, cleaning, and preparing an armature for rewinding C. Demonstrate the loop method of winding a small D.C. armature (Fig. #9) D. Review soldering and testing procedures	Discuss the loop method of winding a small D.C. armature 1. Definition 2. Circuitry 3. Advantages a. Speed of method b. Reduced chance of error c. Ease of testing

16. Lap wind a D.C. armature by the two-in-hand method

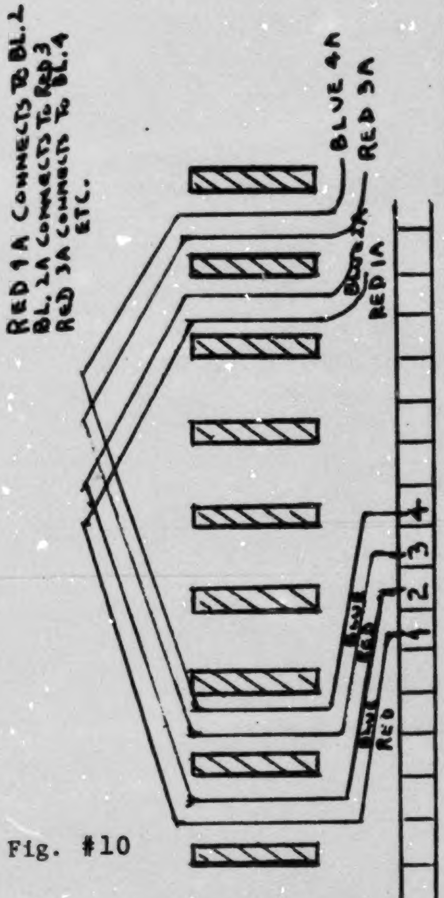

RED 1A CONNECTS TO BL.2
BL. 2A CONNECTS TO RED 3
RED 3A CONNECTS TO BL.4
ETC.
BLUE 4A
RED 3A
BLUE 2A
RED 1A
BLUE
RED
BLUE
RED
1
2
3
4

Fig. #10

A. Discuss and compare the two-in-hand method with heavy wire method and loop method.
B. Demonstrate two-in-hand method of winding an armature (Fig. #10)
   1. Place two pieces of red sleeving on start of coil #1 and two pieces of blue sleeving on start of coil #2
   2. Install start of coils #1 and #2 in commutator
   3. Wind in turns of two coils simultaneously; leave two lead ends out with sleeving for identification
   4. Repeat with each slot until all coils are wound
   5. Ring out coil #1 and place end in proper bar
   6. Follow in sequence: blue, red, blue, until completion

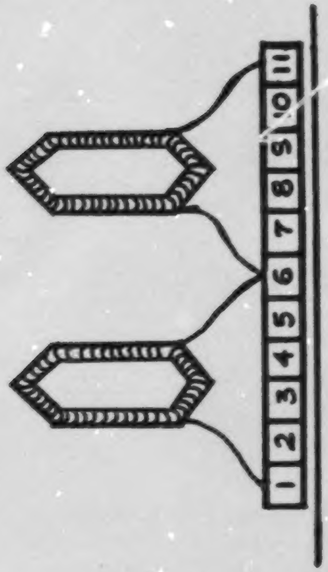
A. Discuss types of insulators used in D.C. repair work
   1. Wire coverings
   2. Slot insulators
   3. Wood and fiber wedges
   4. Cotton, adhensive, varnished tapes
   5. Mica
   6. Vinyl and cotton sleeving
B. Discuss the two-in-hand method of winding D.C. armatures
   1. Definition
   2. Advantages
      a. Time-saving
      b. Reduced possibility of error
      c. Reduced shorting of leads

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
17. Install cord or steel bands on armatures	A. Demonstrate installation of a cord band on a small armature B. Demonstrate installation, method of securing and soldering of a steel band on a large armature	A. Discuss armature bands 1. Purpose a. Keep coils from flying out when armature is revolving b. Keep leads in place behind commutator c. Keep grime and dirt from leads 2. Types a. Steel for large armatures b. Cord for small armatures
18. Turn down and undercut a commutator	A. Demonstrate 1. Placing armature in chuck and center of tail stock, commutator out 2. Running lathe at medium speed with direction of rotation toward operator, using pencil to check for true turning 3. Setting tool bit slightly below commutator center 4. Taking small cuts until commutator is smooth 5. Taking final cut at high speed 6. Using hacksaw blade to clean out mica slots 7. Touching up with smooth sandpaper	A. Discuss the lathe 1. Parts: chuck, tail stock with center, carriage, tool holder, tool post, tool bit 2. Applications in motor repair work 3. Demonstration of safety procedures in using lathe B. Discuss armature turning down 1. Purpose: Smoothing commutator surface so brushes will make good contact with minimum of wear 2. Process: Removal of excess solder from commutator after rewinding, or removing grooves and ridges caused by operational wear

19. Set neutral on a D.C. motor	A. Demonstrate various methods of setting neutral 1. Apply normal current to armature and intopole circuit with no field current Armature will not turn with brushes in neutral 2. Field kick method: Put a voltmeter across brushes; apply current to field. At neutral, there will be no kick on meter 3. Run motor loaded in both directions; in neutral, speeds should be identical. 4. Run motor loaded; at neutral, there will be minimum brush sparking	Discuss neutral point on D.C. motors 1. Definition and theory 2. Effects of improper neutral setting 3. Point of neutral setting 4. Interpole and noninterpole motors
20. Test for and remove defective field coils on a D.C. motor	A. Demonstrate tests 1. Grounds in complete field circuit or individual field 2. Opens in complete field circuit or individual field 3. Shorts a. Drop-in-voltage method b. Resistance test c. Transformer test B. Demonstrate removal of a defective field for rewinding 1. Marking of pole pieces so residual magnetism is not disturbed 2. Removing pole pieces using screwdriver or allen wrench 3. Separating coil from core trying to retain coil shape for rewinding purposes	

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
21. Record data and rewind field coils for a D.C. motor	Demonstrate 1. Taking data a. Wire size with wire gauge or micrometer b. Counting turns if heavy gauge wire c. Recording weight if light gauge wire d. Measuring for form from coil dimensions 2. Constructing form a. Wood or tin b. Correspondence to dimensions of core 3. Winding coils a. Placing form in lathe chuck b. Insulating between form and winding c. Winding of coil in layers If compound coil, the shunt field is wound first and a layer of insulation is placed between fields d. Complete winding by weight or registering turns e. Tying cord in preparation for removal	Discuss rewinding of fields 1. Review taking of data 2. Types and construction of field forms 3. Review lathe parts and operation 4. Materials used in rewinding fields

22. Tape and install field coils; test for polarity, reassemble motor, and test for proper operation.	Demonstrate 1. Taping of each coil with varnished and cotton tape 2. Reinstalling coils into cores and cores to frame 3. Connecting each set of fields for alternate polarity; soldering and taping connections 4. Testing each set of fields for correct polarity, using compass method of polarity testing 5. Reassembling motor and testing under load; there will be a minimum of sparking under load if main series field is correctly connected with respect to interpoles	A. Discuss insulation used in field rewinding 1. Paper 2. Cotton and varnsihed tape 3. Sleeving B. Discuss polarity testing of entire set of fields C. Discuss test for proper interpoles connection after motor is assembled

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
23. Rewind a wave wound armature  Fig. #11	A. Review taking data on D.C. armatures and stress that all items are similar to lap windings except for positioning of leads on commutator B. Demonstrate wave winding procedure (Fig. #11)	Discuss wave windings 1. Definition 2. Application 3. Method of recognition 4. Formula for commutator pitch 5. Special requirements a. Motor must have at least four poles b. Reason for odd number of coils

24. Sand or stone a commutator	A. Demonstrate commutator polishing with sandpaper 1. Sand on lathe, if possible. Use fine finish, such as 4/0 sandpaper 2. If sanding assembled motor, make certain paper is held correctly with regard to direction of rotation B. Demonstrate truing a commutator with a hand stone, moving stone back and forth across commutator to get smooth finish C. Stress safety for both procedures 1. Hold stone securely and at proper angle 2. Wear safety goggles	Discuss commutator problems and their repair 1. High mica results in poor brush contact, which is corrected by undercutting mica with hacksaw blade 2. Defective mica will cause a short or ground. On small motors, the commutator is replaced. On larger machines, the commutator is taken apart and new mica installed 3. Out of round commutator causes brush-bouncing, which is corrected by stoning if minor, or turning down if major 4. Carbonized mica results in shorts; carbon must be cleaned out with hacks blade 5. Grooving results in poor commutation and excessive brush wear, which can usually be stoned satisfactorily

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
25. Change a sleeve bearing ona D.C. motor	A. Demonstrate removal of a sleeve bearing 1. Bearing drive and hammer 2. Bearing drive and arbor press B. Demonstrate installation of a sleeve bearing 1. Bearing drive and hammer 2. Bearing driver and arbor press 3. Reaming bearing to proper size 4. Checking shaft in bearing for free turning	Discuss sleeve bearings 1. Lubrication function 2. Types and composition 3. Styles 4. Principles of lubrication 5. Type oils 6. Wicking systems 7. Ring oiling systems 8. Problems
26. Change a ball bearing on a D.C. motor	A. Demonstrate removal of a ball bearing 1. Use of arbor press 2. Use of bearing pullers B. Demonstrate cleaning a ball bearing 1. Use of cleaning agents 2. Checking whether or not bearing is still good C. Demonstrate installing a ball bearing 1. Use of tubing and hammer 2. Use of tubing and arbor 3. Heating bearing, and freezing shaft on large machines	Discuss ball bearings 1. Parts 2. Classifications 3. Types 4. Seals and shields 5. Lubricants 6. Greasing procedures

27. Knurl a shaft or a sleeve bearing	A. Demonstrate knurling a shaft for replacement of a ball bearing 1. Place armature in lathe 2. Install knurling tool in tool holder 3. Apply tool to shaft portion to be knurled with lathe turning 4. Gradually increase tool pressure until knurl is completed (about .010 inches) B. Demonstrate knurling a sleeve bearing to fit a worn housing 1. Place sleeve bearing on mandrill snugly 2. Place mandrill in lathe chuck 3. Knurl bearing	Discuss knurling 1. Definition 2. Applications in motor repair work 3. Types of knurling tools 4. Limitations
28. Replace and seat brushes on a D.C. motor	A. Demonstrate removal of brushes from brush rigging B. Demonstrate replacement of brushes C. Demonstrate seating of brushes 1. Place brush in holder 2. Draw sandpaper between brush and commutator to seat brush to curve 3. Finish with fine sandpaper 4. Clean dust particles D. Demonstrate setting brushholders exactly parallel with axis of the armature and within 1/16" to 1/8" of cummutator	Discuss D.C. motor brushes 1. Purpose 2. Types 3. Brush pressure 4. Brush springs 5. Brush problems

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
29. Trouble shoot D.C. motors for motor failure, motor noise and overheated motor	Set up prefaulted motors and demonstrate 1. Failure of motor to run a. Burned fuses b. Dirty or clogged brushes c. Open armature circuit d. Open field circuit e. Shorted or grounded fields f. Shorted armature or commutator g. Worn bearings h. Grounded brush holders i. Overload 2. Noisy motor a. Worn bearings b. Poor commutations 3. Overheated motor a. Overload b. Sparking c. Tight bearings d. Shorted coil	Discuss the importance of troubleshooting and the job opportunities available 1. Trade associations 2. Labor organizations

30. Troubleshoot D.C. motors for slow-running motors, fast-running motors, and sparking motors

Set up prefaulted motor and demonstrate

1. Slow-running motor
    a. Shorted armature or commutator
    b. Worn bearings
    c. Open armature coil
    d. Brushes off neutral
    e. Overload
    f. Wrong voltage
2. Fast-running motor
    a. Open field circuit
    b. Unloaded series motor
    c. Shorted or grounded field
3. Sparking motor
    a. Poor commutation
    b. Open armature
    c. Wrong interpole polarity
    d. Wrong lead swing
    e. Brushes off neutral
    f. Open field

Review of work done in D.C. motor repairs

1. Armature winding
2. Fields winding
3. Commutator repair
4. Brush installations
5. Bearings installation
6. Lathe work
7. Testing procedures

Unit III: D.C. Motor Controls

Level Three: Motors and Controls
Suggested Time: *200 Hours / 300 Periods*

Performance Objectives

Upon completion of this unit the student will be able to:

- Connect a shunt motor to be controlled by a safety switch with an external resistance.
- Connect a shunt motor using a three-point starter for starting purposes.
- Connect a shunt motor to a dynamic braking system to stop the motor.

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
1. Connect a shunt motor to be controlled by a safety switch with an external resistance in the armature circuit	A. Display a shunt motor and briefly describe its operation B. Explain why external resistance is needed in the armature circuit C. Develop job circuit on chalkboard D. Demonstrate mounting of controls equipment E. Demonstrate job wiring procedures F. Test motor for proper operation 1. Start motor with resistance in circuit 2. Remove resistance at rated speed 3. Reverse motor direction by interchanging A1 and A2	A. Discuss motor control 1. Meaning 2. Controller functions a. Start b. Stop c. Accelerate d. Decelerate e. Regulate speed f. Plug g. Job h. Brake i. Reverse j. Protection 3. Types of motor control a. Manual b. Semiautomatic c. Automatic

2. Connect a shunt motor with resistance in the armature circuit and a double-pole, double-through switch to reverse motor operation

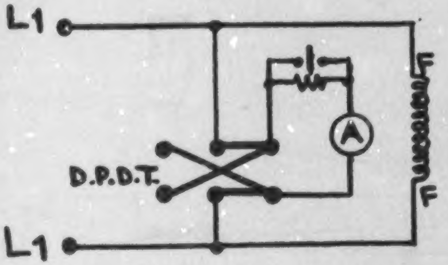
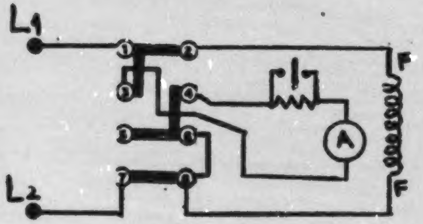
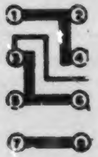


Fig. #1

A. Display a D.P.D.T. switch, illustrate its internal wiring and demonstrate how it can be used to reverse a D.C. motor
B. Develop job circuit on chalkboard
C. Review mounting of equipment
D. Demonstrate job wiring, including connections to D.P.D.T. switch
E. Test job for proper operation
   1. Start motor with resistance in circuit
   2. Remove resistance at rated speed
   3. Reverse motor direction by operation of the D.P.D.T. switch
      Safety: Emphasize motor must come to a stop before reversing is performed

A. Discuss D.C. motors
   1. Definition
   2. Advantages
   3. Disadvantages
   4. Types
      a. Series
      b. Shunt
      c. Compound
   5. Applications for each type
B. Discuss double-pole, double-throw switches
   1. Construction
   2. Application

Tasks	TEACHING CONTENT	
	Development of Skills	Development of Related Information
3. Connect a shunt motor with resistance in the armature circuit and a drum switch for reversing motor rotation  L1 L2 F F A 1 2 3 4 5 6 7 8 Fig. #2  Fig. #3	A. Display a drum switch, illustrate its internal circuitry and demonstrate its operation in a circuit B. Develop job circuit on chalkboard C. Review job mounting procedures D. Demonstrate job wiring including connecting to drum switch E. Test job for proper operation 1. Start motor with resistance in circuit 2. Remove resistance at rated speed 3. Reverse motor direction by operation of the drum switch	A. Discuss drum switches 1. Purpose 2. Advantages compared to the D.P.D.T. switch 3. Circuit applications for both D.C. and A.C. motors 4. Types 5. Typical circuitry

4. Connect a shunt motor, using a three point-starter for starting purposes

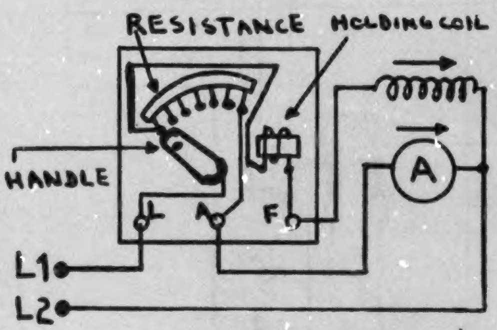
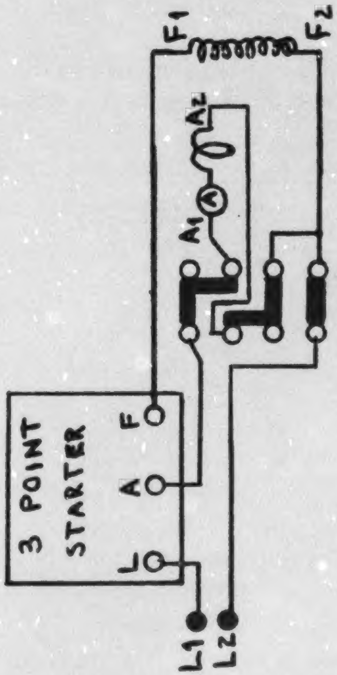


Fig. #4
A three-point starting box connected to a shunt motor

A. Display a three-point starter and demonstrate its operation. Use Fig. #4) to trace circuitry
B. Develop job circuit on chalkboard
C. Demonstrate how heavy equipment is mounted
D. Demonstrate job wiring procedures
E. Test job for correct operation
   1. Operate three-point starter
   2. Demonstrate action of holding coil
   3. Demonstrate "no field" release by opening field circuit

A. Discuss three-point starters
   1. Purpose
   2. Construction
   3. Operation
   4. Circuitry
   5. Advantage-"no field" release

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
5. Connect a shunt motor, using a three-point starter for starting purposes and a drum switch for reversing rotation  Fig. #5	A. Display a drum switch which is different from the one used in task #3. Illustrate and trade its circuitry B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedure E. Test job for proper operation 1. Operate motor from three-point starter 2. Reverse motor direction by operation of the drum switch	A. Discuss construction of D.C. motors 1. Magnetic circuit a. Yoke b. End shields c. Armature core d. Field core e. Air gap 2. Electric circuit a. Armature windings b. Field windings c. Commutator d. Brushes 3. Interpoles, if used

6. Connect a shunt motor using a four-point starter for starting purposes

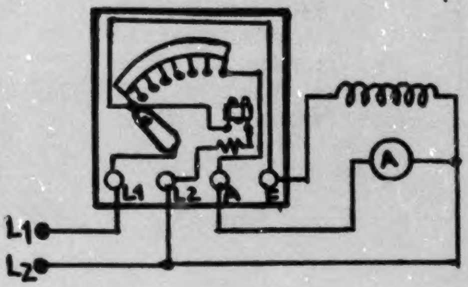


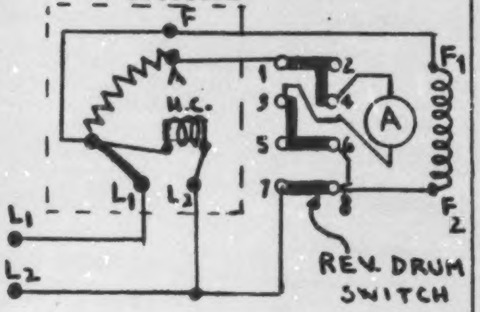
Fig. #6

A. Display a four-point starter, and demonstrate its operation. Use Fig.#6) to trace its circuitry
B. Develop job circuit on chalkboard
C. Review demonstration for mounting heavy equipment
D. Demonstrate wiring of circuit including connections for four-point starter
E. Test job for correct operation
  1. Operate four-point starter
  2. Demonstrate action of the holding coil
     Note: Low voltage release can be demonstrated by addition of a resistance with a shunt out switch connected in the line

A. Discuss the four-point starter
  1. Purpose
  2. Construction
  3. Operation
  4. Circuitry
  5. Advantage: "no voltage" release

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
7. Connect a shunt motor with resistance in the armature for starting and a rheostat in the field circuit for speed control from normal to above normal	A. Display a field rheostat and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation 1. Start motor with resistance in circuit 2. Remove resistance at rated speed 3. Vary speed from normal to above normal with field rheostat	A. Discuss above normal speed control 1. Definition 2. How obtained 3. Theory of speed control B. Discuss field rheostats 1. Construction 2. Connection in a circuit
8. Connect a shunt motor resistance in the armature circuit for starting and a rheostat in the armature to control speed from normal to below normal	A. Display an armature rheostat, its size to a field rheostat and demonstrate its operation B. Develop job circuit on chalkboard C. Review of equipment mounting D. Review wiring of equipment including connections to armature rheostat E. Test job for proper operation 1. Start motor with resistance in circuit 2. Remove resistance at rated speed 3. Vary speed from normal to below normal with armature rheostat	A. Discuss back E.M.F. 1. Definition 2. Importance of limiting armature current to a safe value 3. Theory 4. Working out several examples for values of back E.M.F. and effective voltage B. Discuss armature rheostats 1. Compare construction to field rheostats 2. Connection in a circuit

9. Connect a shunt motor with: resistance in the armature circuit for starting A field rheostat for above normal speed control An armature rheostat for below normal speed control	A. Review theory of speed control in D.C. motors B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation 1. Vary motor speed from normal to above normal with field rheostat 2. Vary motor speed from normal to below normal with armature rheostat	A. Discuss armature reaction in D.C. motors 1. Definition 2. Cause 3. Effects 4. Corrections a. Noninterpole motors b. Interpole motors

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
10. Connect a shunt motor with a four-point starting box for starting purposes and a drum switch to reverse motor rotation  F F1 F2 H.C. A 1 2 3 4 5 6 7 8 L1 L2 REV. DRUM SWITCH Fig. #7	A. Review construction and operation of the four-point starting box and the drum switch B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job-wiring procedures E. Test job for proper operation 1. Bring motor to speed by operation of a four-point starter 2. Reverse motor rotation by operation of the drum switch	A. Discuss interpoles 1. Purpose 2. Construction 3. Physical location 4. Circuit connection 5. Testing for correct polarity in relation to armature
11. Connect a shunt motor with a four-point starter for starting purposes and with a field rheostat to obtain above normal speeds	A. Review speed control of D.C. motors B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation 1. Bring motor to speed by operation of the four-point starter 2. Vary speed from normal to above normal	A. Discuss types of manual controllers used for D.C. motors 1. Toggle switches 2. Safety switches 3. Drum controllers 4. Face plate starters

12. Connect a compound motor with external resistance for starting purposes, using the long shunt cumulative connection

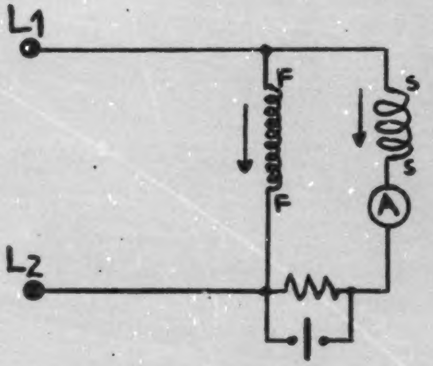
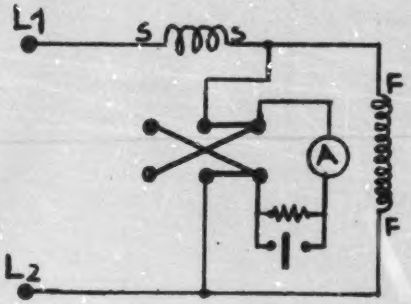
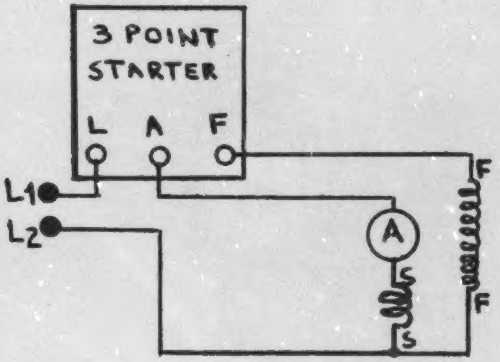


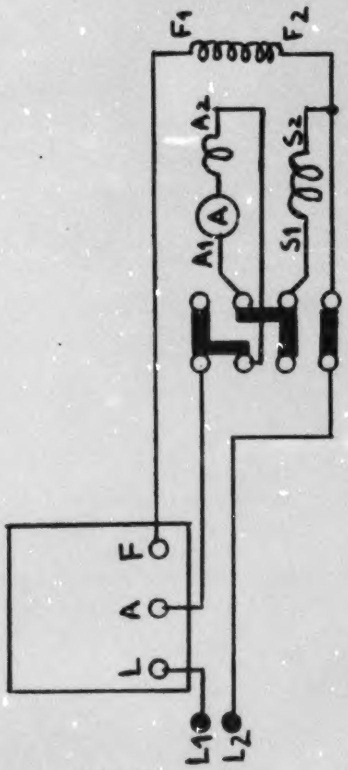
Fig. #8

A. Display a disassembled compound motor, describe its construction and compare it to a shunt motor
B. Develop job circuit on chalkboard
C. Review mounting of equipment
D. Demonstrate job wiring for a long shunt, cumulative connection
F. Test job for proper operation

A. Discuss compound motors
  1. Definition
  2. Construction
  3. Applications
  4. Types

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
13. Connect a compound motor with an external resistance for starting purposes and a double-pole, double-throw switch for reversing rotation, using the short-shunt cumulative connection  Fig. #9	A. Review the cumulative connection and how it is accomplished. Illustrate difference between long shunt and short shunt B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a short shunt, cumulative connection E. Test job for correct operation 1. Run motor in both directions using external resistance for starting purposes	A. Discuss how to locate circuits in an unmarked compound motor 1. Shunt field will show high resistance 2. Series field will show low resistance 3. Armature will also show low resistance but will indicate "open" when brushes are lifted 4. Illustrate and demonstrate the methods noted

14. Connect a compound motor with a three-point starter. Use the long-shunt cumulative connection  3 POINT STARTER L A F L1 L2 A S S F F Fig. #10	A. Review the long shunt cumulative connection and the three-point starter B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for correct operation	A. Discuss speed and torque characteristics of shunt, series and compound motors 1. Compare starting 2. No load to full load 3. Use curves to illustrate

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
15. Connect a compound motor with a three-point starter for starting purposes and with a drum switch to reverse rotation. Use the long-shunt cumulative connection  F1 F2 A2 S2 A1 A S1 F A L L1 L2 157 Fig. #11	A. Review direction reversal in compound motors. Stress reversal of armature only in order to maintain cummulative connection B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation	A. Discuss calculation of motor horsepower 1. Construction and use of a prony brake 2. Working out of several examples, using Formula: $HP = \frac{6.20 \times R.P.M. \times LxP}{33,000}$ 3. Stressing of safety during use of prony brake

16. Connect a compound motor with a four-point starter. Use the short-shunt cumulative connection	A. Review the short shunt cumulative connection B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation	A. Discuss the D.C. motor name plate and explain meaning and purpose of each item 1. Horsepower 2. R.P.M. 3. Volts 4. Amperes 5. Degrees C rise 6. Service factor 7. Duty 8. Code 9. Manufacturer's information a. Name b. Type c. Style d. Serial e. Frame

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
17. Connect a compound motor with a four-point starter for starting purposes and with a drum switch to reverse rotation. Use the long-shunt commulative connection	A. Review how to locate circuits in an unmarked compound motor. Have students demonstrate procedure. B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation	A. Discuss full load current ratings of D.C. motors (N.E.C., Article 430: Table 147) 1. Explain purpose of the table 2. Have students use table
18. Connect a compound motor with a four-point starter for starting purposes, with a drum switch to reverse rotation; and with a field rheostat for above-normal speed control. Use the long shunt comulative connection	A. Review face plate starters: purpose, construction and circuit connections B. Develop job circuit on blackboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation	A. Discuss code regulations for typical D.C. motors (N.E.C., Article 430). Work out examples for various size motors for the following: 1. Full load current 2. Conduit size 4. Branch circuit protection size 5. Controller size

19. Connect a shunt motor controlled by an across-the-line magnetic starter, operated from a two-wire pilot device

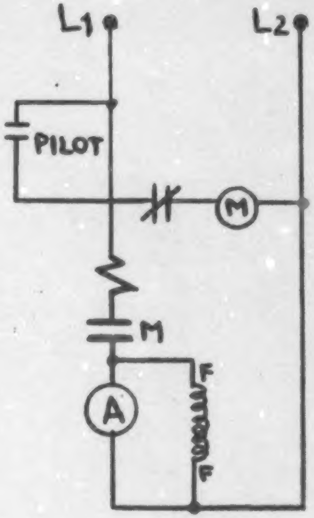
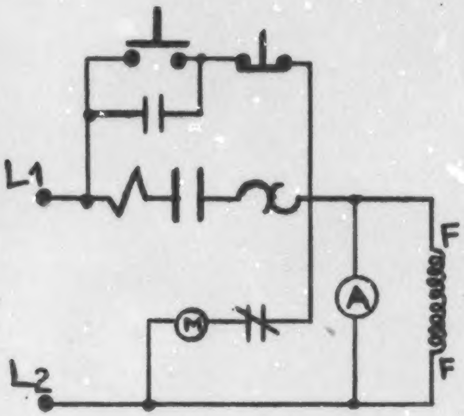
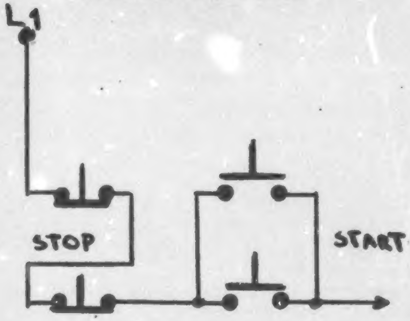


Fig. #12

A. Review the shunt motor
B. Display a magnetic starter and demonstrate its operation
C. Display two wire pilot devices and demonstrate their operation
D. Develop job circuit on chalkboard
E. Review mounting of equipment
F. Demonstrate job wiring for a two-wire automatic control circuit
G. Test job for proper operation
    1. Point out automatic starting and stopping of motor from pilot device

A. Discuss magnetic starters
    1. Definition
    2. Advantages
    3. Construction
    4. Internal wiring
B. Discuss two wire pilot devices
    1. Float switch
    2. Pressure switch
    3. Time clock
    4. Thermostat
    5. Limit switch
    6. Photo cell

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
20. Connect a shunt motor controlled by an across-the-line magnetic starter operated from a start-stop push button station (see Fig. #13)  Fig. #13	A. Display a start-stop control station, describe its construction, illustrate its circuitry, and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a three-wire automatic control circuit E. Test job for correct operation from the start-stop control station	A. Discuss a three-wire automatic control of D.C. motors 1. Meaning 2. Advantages 3. Circuitry 4. Start-stop control stations

21. Connect a compound motor controlled by an across-the-line magnetic starter operated from a start-stop station and an emergency stop station Use the long shunt cumulative connection	A. Describe the purpose and connection of emergency stop stations B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring of emergency stop stations E. Test job for proper operation from both control stations	A. Discuss types of protection provided in magnetic starters 1. No-voltage or low-voltage 2. Motor over current a. Thermal relays construction and operation
22. Connect a shunt motor controlled by an across-the-line magnetic starter operated from two start-stop push-button stations  Fig. #14	A. Describe and illustrate how start or stop buttons are connected when used in multiple B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for two start-stop control stations E. Test job for correct operation for both stations	A. Discuss tools and devices used for mounting electrical equipment 1. Tools a. Carbide masonry drills b. Hand star drill c. Twist point drill d. Expander setting tool 2. Devices a. Toggle bolts b. Expansion shields c. Screw anchors

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
23. Connect a compound motor controlled by an across-the-line starter, operated from two start-stop stations, and a drum switch to reverse rotation. Use the short-shunt cumulation connection	A. Review principle of drum reversing B. Develop job circuit on chalkboard C. Review mounting equipment D. Review job wiring procedures E. Test job for proper operation 1. Start and stopping from either control station 2. Motor reversal	A. Discuss types of enclosures used for motors and motor equipment 1. N.E.C. regulations 2. Types a. General purpose b. Watertight c. Dusttight d. Hazardous locations

24. Connect a compound motor controlled by a reversing magnetic starter operated from a forward-reverse-stop station. Use the long-shunt cumulative connection

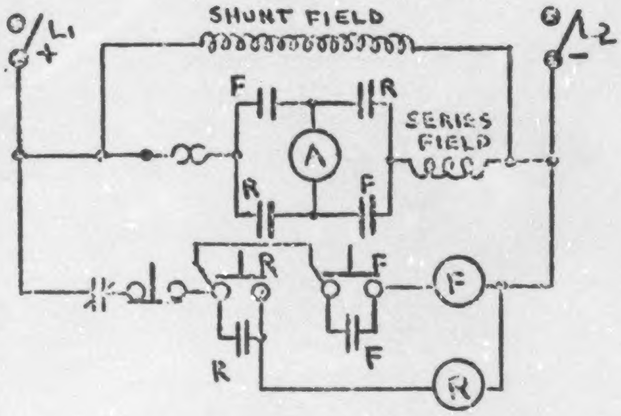


Fig. #15

A. Display a magnetic reversing starter; illustrate its internal construction and circuitry, and demonstrate its operation
B. Develop job circuit on chalkboard
C. Review mounting of heavy equipment
D. Demonstrate job wiring for reversing magnetic starter circuit
E. Test job for proper operation
   1. Start and stop motor in forward position
   2. Start and stop motor in reverse position

A. Discuss magnetic reversing of D.C. motors
   1. Advantages over manual reversing
   2. Construction of starters
   3. Types of starters
   4. Internal wiring of a typical starter

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
25. Connect a compound motor controlled by a magnetic reversing starter operated from a forward-reverse-stop station and an emergency stop station at a remote location. Use the long shunt cumulative connection	A. Review construction and operation of magnetic reversing starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation from the reversing starter and the emergency stop station	A. Discuss the blowout coil used in D.C. magnetics 1. Purpose 2. Principle of operation 3. Circuitry B. Discuss the shaded coil used in magnetic starters 1. Purpose 2. Principle of operation
26. Connect a shunt motor controlled by a magnetic reversing starter operated from two forward-reverse-stop stations	A. Review connection of start and stop buttons when used in multiple B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring of two forward-reverse-stop stations E. Test job for correct operation from two control stations	A. Discuss electrical interlocking in magnetic reversing circuits 1. Purpose 2. Circuitry B. Discuss mechanical interlocking in magnetic reversing starters 1. Purpose 2. Construction

27. Connect a compound motor controlled by a dashpot starter operated from a start-stop pushbutton station

A. Display a dashpot starter, illustrate its circuitry and demonstrate its operation
B. Develop job circuit on chalkboard
C. Demonstrate mounting of dashpot starter
D. Demonstrate job wiring from dashpot starter
E. Test job for proper operation
   1. Adjust time delay by varying action of dashpot

A. Discuss reduced volts starting of D.C. motors
   1. Purpose
   2. Mechanical time delay
      a. Dashpot
      b. Escapement and friction types
   3. Electrical time delay
      a. Counter E.M.F.
      b. Definite magnetic time
      c. Current lockout
      d. Electrical timers

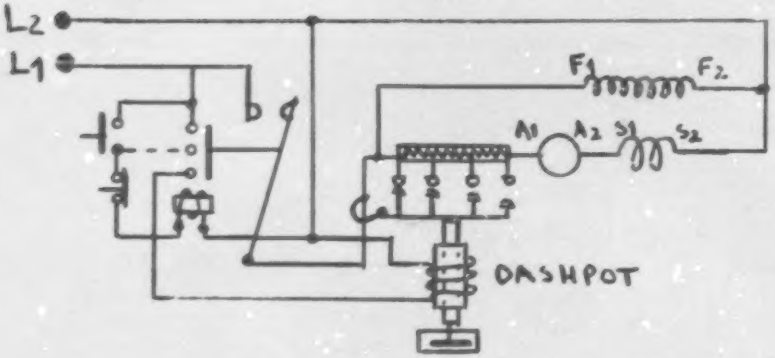


Fig. #16

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
28. Connect a shunt motor controlled by a dashpot starter operated from two start-stop-stations	A. Develop job circuit on chalkboard B. Review mounting of equipment C. Review job wiring procedures D. Test job for proper operation from two control stations	A. Discuss dashpot starters 1. Purpose 2. Construction 3. Internal wiring 4. Principle of operation a. Solenoid in oil operation
29. Connect a compound motor controlled by a dashpot starter, operated from two start-stop stations and a drum switch to reverse rotation	A. Review dashpot starters a. Construction b. Operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for correct operation from two control stations and drum switch	A. Discuss problems found on D.C. contactors 1. Burning and welding of contacts and shunts 2. Blowout coil overheats 3. Failure to pick up 4. Broken flexible shunt 5. Failure to drop out 6. Insulation failure 7. Coil failure

30. Connect a shunt motor controlled by an across-the-line magnetic starter operated from a start-stop-jog station

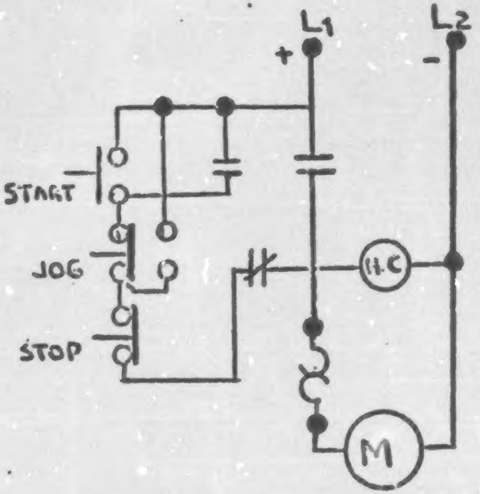
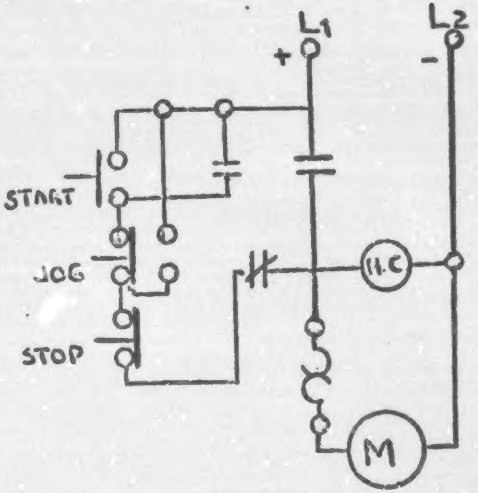


Fig. #17

A. Display a jog button; describe its construction and operation
B. Develop job circuit on chalkboard
C. Review mounting of equipment
D. Demonstrate job wiring for a jog circuit
F. Test job for proper operation from start-jog-stop station

A. Discuss "jogging"
   1. Definition
   2. Purpose
   3. Construction of jog station
   4. Circuitry
   5. Types of jogging

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
30. Connect a shunt motor controlled by an across-the-line magnetic starter operated from a start-stop-jog station  Fig. #18	A. Display a jog button; describe its construction and operation B. Develop job circuit on blackboard C. Review mounting of equipment D. Demonstrate job wiring for a jog circuit F. Test job for proper operation from start-jog-stop station	A. Discuss "Jogging" 1. Definition 2. Purpose 3. Construction of jog station 4. Circuitry 5. Types of jogging

31. Connect a shunt motor controlled by an across-the-line magnetic starter operated from a start-stop station and start-stop-jog station	A. Review purpose and principles of jogging B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring E. Test job for proper operation from two control stations	A. Discuss code regualtions (N.E.C., Article 430:H) regarding disconnecting motors 1. Location 2. Grounding conductor 3. Ampere ratings 4. Types
32. Connect a compound motor controlled by an across-the-line starter operated from a start-stop station with a pilot light to indicate that the motor is running	A. Display a pilot light and describe its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for pilot light circuit E. Test job for proper operation	A. Discuss pilot lights 1. Purposes a. Motor running b. Motor off c. Trouble in circuit 2. Circuiting B. Discuss code regulations (N.E.C., Article 430:C) for motor and branch-circuit overload protection

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
33. Connect a shunt motor controlled by a definite-time magnetic starter operated from a start-stop station	A. Display a definite time magnetic starter, illustrate its circuitry and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of heavy equipment D. Demonstrate job wiring of a definite time starter E. Test job for proper operation 1. Adjust spring tension to vary timing	A. Discuss "definite time" magnetic starters 1. Purpose 2. Construction 3. Principle of operation 4. Circuitry 5. Types

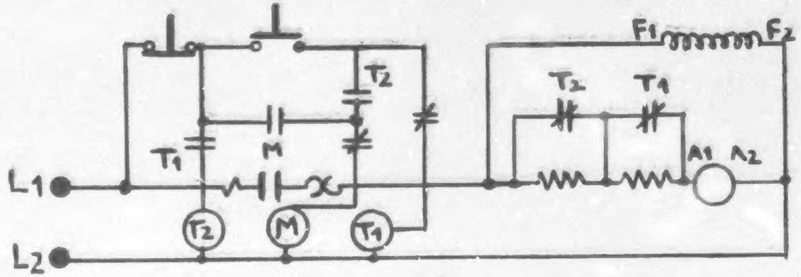


Fig. #19

Two-step definite magnetic time starter connected to a shunt motor

34. Connect a shunt motor controlled by a definite time magnetic starter, operated from two start-stop stations, and a drum switch for reverse rotation	A. Review purpose, construction and operation of definite time magnetic starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for correct operation from two control stations and from drum switch	A. Discuss code regulations (N.E.C. Article 430:D) for motor branch-circuit short-circuit and ground-fault protection 1. Individual motors 2. Several motors on one branch 3. Protective devices 4. Size of fuse holder 5. Rating of circuit breaker

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
35. Connect a compound motor controlled by a one-coil lockout starter operated from a start-stop station	A. Display a one-coil lockout; illustrate its circuitry and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a one-coil lockout starter E. Test job for correct operation from the control station	A. Discuss lockout starters 1. Purpose 2. Construction 3. Principle of operation 4. Circuitry

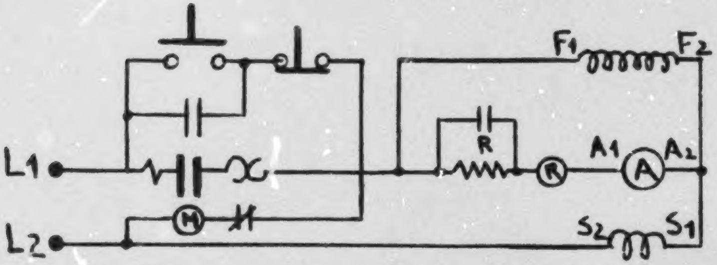


Fig. #20

One-coil current-lockout starter with magnetic controls connected to compound interpole motor

36. Connect a compound motor controlled by a two-coil lockout starter operated from a start-stop station	A. Display a two-coil lockout starter; illustrate its circuitry and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of heavy equipment D. Demonstrate job wiring for two-coil lockout starter circuit E. Test job for proper operation from control station	A. Discuss two-coil lockout starters 1. Purpose 2. Construction 3. Principle of operation 4. Circuitry
37. Connect a shunt motor controlled by a one-coil lockout starter operated from two stop-start stations	A. Review construction and operation of lockout starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation from two control stations	A. Discuss code regulations (N.E.C., Article 430: F) for motor control circuits 1. Overcurrent protection 2. Protection of conductors 3. Disconnection

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
38. Connect a shunt motor controlled by a counter E.M.F. starter operated from a start-stop station	A. Display a counter E.M.F. starter; illustrate its circuitry and demonstrate its operation B. Develop job circuit on chalkboard C. Demonstrate mounting of counter E.M.F. starter D. Demonstrate job wiring for a counter E.M.F. starter circuit E. Test job for proper operation from control station	A. Discuss counter E.M.F. starters 1. Purpose 2. Construction 3. Principle of operation 4. Circuitry

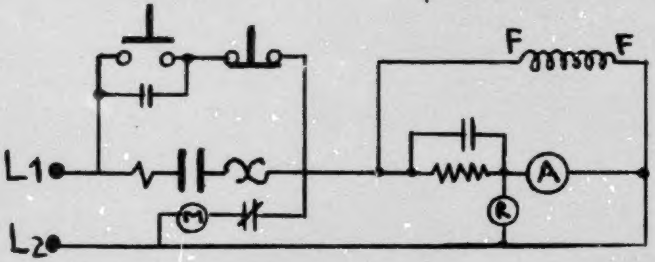


Fig. #21
Cemf starter with one step of starting resistance connected to a shunt motor

39. Connect a compound motor controlled by a counter E.M.F. starter operated from two start-stop stations	A. Review construction and operation of counter E.M.F. starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for correct operation from two control stations	A. Discuss electric brakes used to stop D.C. motors 1. Purpose 2. Construction 3. Advantages over A.C. brakes 4. Principle of operation

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
40. Connect a shunt motor to a dynamic braking system to stop the motor	A. Display a starter equipped with a dynamic braking; illustrate and demonstrate its operation B. Develop job circuit on chalkboard C. Review job mounting procedures D. Demonstrate job-wiring for a dynamic braking system E. Test job for proper operation from the control station	A. Discuss dynamic braking 1. Purpose 2. Principle of operation 3. Circuitry for D.C. operation

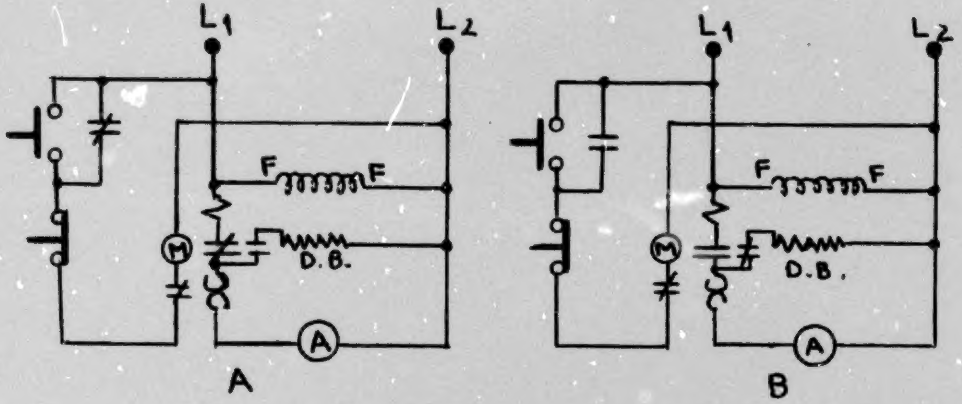


Fig. #22
Dynamic braking system with starter connected to a shunt motor: (a) running (b) braking

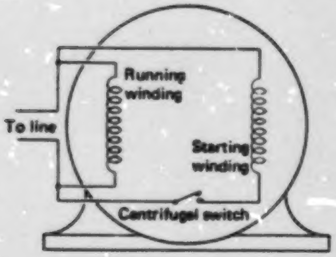
Unit IV: A.C. Motor Repair and Rewinding

Level Three: Motors and Controls
Suggested Time: *100 Hours / 150 Periods*

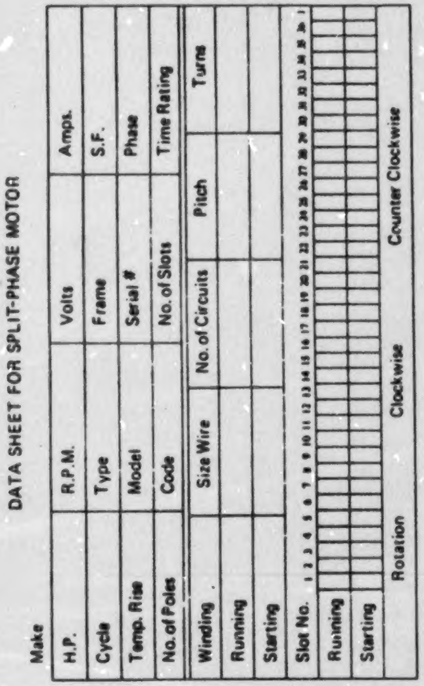
Performance Objectives

Upon completion of this unit the student will be able to:

- Disassemble and assemble, run and test a rewound split phase motor.
- Record data for rewinding a three-phase motor.
- Strip, clean, deburr, and insulate the slots on a three-phase stator.
- Disassemble, repair, and reassemble universal motors.

Tasks	TEACHING CONTENT	
	Development of Skills	Development of Related Information
1. **Disassemble a split-phase motor**  Running winding To line Starting winding Centrifugal switch Fig. #1	A. Display a split-phase motor and describe several reasons why it would become necessary to disassemble it B. Demonstrate 1. Center punching end shields and stator for reassembling purposes 2. Removing pulley and key from shaft 3. Removing end shields and rotor 4. Inspecting all parts a. centrifugal switch b. bearings c. shaft d. windings 5. Making a wiring diagram for internal connections, if necessary 6. Taking motor name plate data and recording in card file	A. Discuss split-phase motors 1. Definition 2. Sizes 3. Advantages 4. Disadvantages 5. Applications 6. Basic circuit (Fig. #1) B. Discuss basic hand tools 1. Hammers: hard and soft face 2. Center punch 3. Wrenchs a. open end b. box c. ratchet d. spin tights C. Describe and demonstrate safety in handling of motors and tools 1. Proper lifting 2. Stable work surfaces
2. **Assemble a split-phase motor**	A. Display a disassembled split-phase motor and discuss need for care in reassembling it B. Demonstrate 1. Checking shaft, stator core and rotor core for burrs 2. Checking that windings will not touch fan or end shields 3. Installing centrifugal switch 4. Installing end shields 5. Check rotor for free turning and excessive end play 6. Lubricating bearings	A. Discuss split-phase motor parts. 1. Construction and function a. rotor b. stator c. centrifugal switch d. end shields e. bearings, shaft, fan B. Describe and demonstrate safety in reassembling split phase motors 1. Hitting fingers with mallets 2. Catching fingertips between end plates and stator frames 3. Dropping components or tools 4. Using the proper tools

3. Record data for rewinding a split-phase stator (Fig. #2)



DATA SHEET FOR SPLIT-PHASE MOTOR

Make			
H.P.	R.P.M.	Volts	Amps.
Cycle	Type	Frame	S.F.
Temp. Rise	Model	Serial #	Phase
No. of Poles	Code	No. of Slots	Time Rating

Winding	Size Wire	No. of Circuits	Pitch	Turns
Running				
Starting				

Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	1
Running																																					
Starting																																					

Rotation	Clockwise	Counter Clockwise

Fig. #2

A. Display a split phase stator and describe why it is necessary to record correct data

B. Demonstrate recording of winding data

1. Making a layout of the physical position of the two windings
2. Recording number of poles
3. Recording coil spans in each winding
4. Recording number of turns in each winding
5. Measuring wire size of each winding
6. Measuring insulation size
7. Determining connection for each winding
8. Checking distance windings extend beyond core

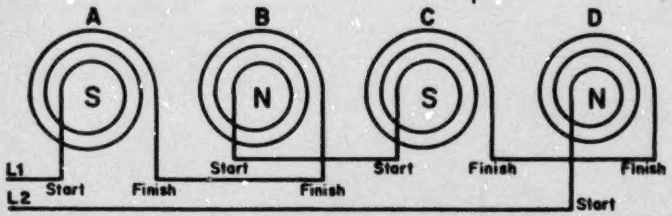
A. Discuss split phase motor theory

1. Starting-displacement of two windings
2. Starting torque
3. Speed regulation
4. Direction determination
5. Reversing of rotation

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
4. Strip, clean, and deburr a split phase stator	A. Discuss importance of stripping and cleaning a core properly B. Display problems that result from poor work C. Describe how stators are heated to loosen wires for stripping D. Demonstrate 1. Removing wedges 2. Removing old coils from slots 3. Removing old slot insulation 4. Straightening core slots, if necessary 5. Removing burrs from all areas, if necessary	A. Discuss how speed of induction motors is determined 1. Meaning of mechanical degrees 2. Meaning of electrical degrees 3. Formula for induction motors speed: $S = \frac{F \times 60}{\text{Pole Pairs}}$ 4. Work out several examples using formula B. Discuss stripping tools 1. Wedge driver 2. Heavy hacksaw blade 3. Diagonals 4. Files C. Describe and demonstrate safety practices in stripping and cleaning 1. Need for goggles 2. Avoiding lacerating fingers
5. Cut and install slot insulators on a split phase motors	A. Discuss the importance of proper preparation of core for rewinding B. Demonstrate 1. Checking removal of old insulation 2. Straightening and tightening laminations 3. Removing burrs with a file 4. Measuring and cutting insulation 5. Folding and shaping insulation 6. Inserting insulation	A. Describe the wire guage and micrometer 1. Construction 2. Method of reading 3. Method of checking sizes of wire B. Discuss slot insulations 1. Types 2. Thicknesses 3. Applications C. Discuss tools used in preparing a stator core 1. Paper cutter 2. Folder D. Discuss avoiding paper cuts on hands

6. Install the running winding on a split-phase stator	A. Refer to data chart for discussion on how to install the running winding B. Demonstrate 1. Making coils on a machine, using winding head 2. Inserting winding in first pole using correct coil pitches. Bring out start and finish leads 3. Repeat on all poles	A. Discuss reasons why running winding is generally installed first in core B. Discuss methods of installing a running winding 1. Hand 2. Machine formed coils
7. Install the starting winding on a split-phase stator	A. Refer to data chart for discussion on how to install the starting winding B. Demonstrate 1. Insulating between starting and running winding 2. Making starting winding using either a skein or winding head 3. Inserting winding in first pole, using correct pitches and placing in proper relation to running winding. Bring out start and finish leads 4. Repeat on all poles	A. Discuss reasons why starting winding is generally installed on top of running winding B. Discuss methods of installing a starting winding 1. Hand 2. Skein 3. Machine formed coils

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
8. Connect the windings on a split-phase stator	A. Discuss the salient series connection and illustrate how it is made B. Demonstrate 1. Inserting sleeving on leads 2. Connecting running winding 3. Connecting starting winding 4. Soldering and insulating all splices	A. Discuss winding connections and magnetism principles 1. Salient poles 2. Consequent poles 3. Series connection 4. Multi-circuit connection B. Discuss soldering methods 1. Types of guns and irons 2. Types of solder 3. Safety practices 4. Need for goggles



Similarity of formation of magnetic poles with concentraded and distributed windings

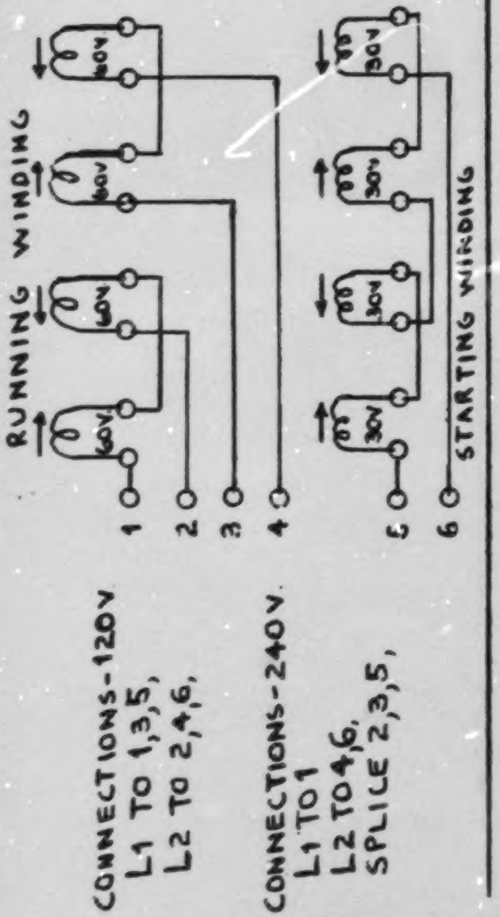
Fig. #3

9. Test a rewound split-phase stator for grounds, opens, shorts, and reverses	A. Demonstrate 1. Use of series lamp tester to test for grounds 2. Use of series lamp tester to test for circuit open and then to isolate open 3. Use of growler to locate shorts 4. Use of test rotor or compass to test for reverses	A. Discuss grounds, opens, shorts, and reverses 1. Definition 2. Causes 3. Effects 4. Testing methods B. Discuss the megger and internal growler 1. Purpose 2. Construction 3. Use
10. Tie windings; varnish and bake a rewound stator	A. Discuss reasons why a stator must be tied securely B. Demonstrate 1. Checking the dimensions of winding overhang for correctness 2. Checking to ascertain that no wires touch core 3. Shaping and tying windings 4. Preheating stator 5. Impregnating with insulating varnish 6. Baking stator 7. Cleaning stator after baking	A. Discuss impregnating and baking stators 1. Purpose 2. Methods 3. Types of varnish and solvents 4. Baking temperature

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
11. Assemble, run, and test a rewound split-phase motor	A. Display a split-phase motor ready for reassembling and discuss need for all parts to be in good working order B. Demonstrate 1. Checking for burrs and high spots on parts 2. Checking the bearings 3. Checking the centrifugal device 4. Assembling the parts 5. Checking for free turning and excessive end play 6. Testing for ground 7. Running motor and checking current with an amprobe 8. Running motor and checking for overheating or improper sound	A. Discuss the A.C. Clamp-on ammeter 1. Defintion 2. Advantage 3. Principle of operation 4. Reading scales 5. Illustrating scales on chalkboard and giving students practice in reading

12. Connect a dual voltage single-phase motor

Fig. #4


RUNNING WINDING
STARTING WINDING
30V
30V
30V
30V
60V
60V
60V
60V
1
2
3
4
5
6
CONNECTIONS-120V
L1 TO 1,3,5,
L2 TO 2,4,6,
CONNECTIONS-240V
L1 TO1
L2 TO4,6,
SPLICE 2,3,5,

A. Display a dual voltage single-phase motor and demonstrate that it can be used on two voltages

B. Demonstrate
   1. Two parallel connection of running winding
   2. Series connection of starting winding
   3. Marking of six external leads
   4. Connecting for low volts - running clockwise and counter-clockwise
   5. Connecting for high volts - running clockwise and counter-clockwise

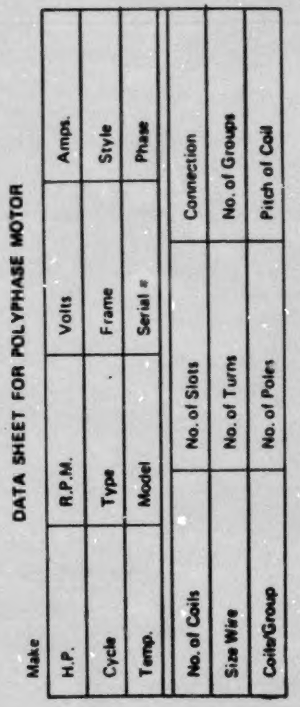
A. Discuss advantages of using higher voltages on electrical circuits
   1. Reduced size of conductors and equipment
   2. Reduced labor costs
   3. Reduced voltage drop

B. Discuss advantage of a dual voltage motor

C. Discuss theory of dual voltage circuitry (Fig. #4)
   1. Voltage in each pole remains the same regardless of connection

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
13. Replace the centrifugal device on a split-phase motor	A. Display a split-phase motor and connect. Have students note click as motor comes to speed. Explain that clicking sound is caused by operation of centrifugal switch B. Demonstrate 1. Cleaning contacts on stationary part 2. Removing stationary part after marking and unsoldering leads 3. Replacing stationary part and resoldering leads 4. Removing moving part 5. Replacing moving part 6. Checking for proper operation of both stationary and moving parts	A. Discuss the centrifugal switch 1. Purpose 2. Principle of operation 3. Types 4. Applications 5. Common problems

14. Record data for rewinding a three-phase motor (Fig. #5)



DATA SHEET FOR POLYPHASE MOTOR

Make

H.P.	R.P.M.	Volts	Amps.
Cycle	Type	Frame	Style
Temp.	Model	Serial #	Phase

No. of Coils	No. of Slots	Connection
Size Wire	No. of Turns	No. of Groups
Coils/Group	No. of Poles	Pitch of Coil

Fig. #5

A. Discuss importance of taking correct winding data

B. Demonstrate recording data
   1. Checking connection type
   2. Determining number of poles
   3. Determining number of slots
   4. Determining number of coils
   5. Determining number of groups and coils per group
   6. Checking coil per inch
   7. Determine number of turns in each coil
   8. Checking wire size
   9. Checking distrance of coil overhang

A. Discuss three phase systems
   1. How generated
   2. Advantages over single-phase

B. Discuss advantages of three-phase motors
   1. Simple construction
   2. Little maintenance
   3. Reliable
   4. High output for physical size

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
15. Strip, clean, deburr, and insulate slots on a three-phase stator	A. Discuss importance of proper preparation of a stator to be rewound B. Demonstrate 1. Removal of old wire and insulation 2. Straightening and deburring of laminations 3. Measuring and cutting slot insulators 4. Cutting slot and phase separators 5. Cutting, forming and installing slot insulation	A. Discuss three-phase motor construction 1. End shields 2. Rotor 3. Stator B. Discuss types and purpose of insulation used in rewinding three-phase stators
16. Make coils for a three-phase stator	A. Discuss importance of making coils correctly B. Review coil specifications for the job C. Explain that three phase coils are form wound on a machine D. Demonstrate 1. Setting dimensions on winding head 2. Making sample coil and test in stator, using correct pitch Adjusting coil dimensions, if necessary 3. Winding required number of coil groups installing sleeving at lead ends	A. Discuss three-phase motor theory 1. Rotating magnetic field 2. Synchronous speed and rotor speed 3. Formula for synchronous speed: $S = \frac{F \times 60}{PP\ (\text{Pole Pairs})}$ B. Define "slip" 1. Relationship of slip to torque

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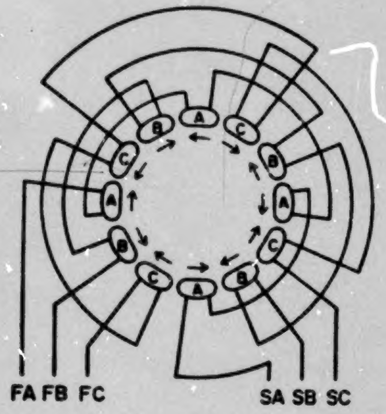
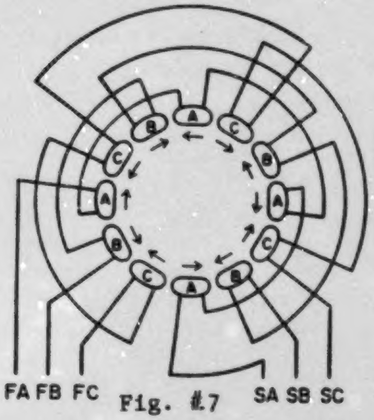
17. Install coils on a three-phase stator	A. Review procedures and materials for rewinding a three-phase stator B. Demonstrate 1. Winding all coil groups in same direction 2. Leaving out core top side of several coils to be determined by pitch 3. Winding in bottom and top sides of remaining coils 4. Installing top side of coils left hanging 5. Bringing out all leads on a common side	A. Discuss the squirrel-cage rotor 1. Construction 2. Principle of operation 3. Rotor speed 4. Purpose of skewing 5. Double-bar type 6. Torque and slip B. Calculate efficiency of a motor $E = \frac{\text{Output}}{\text{Input}}$

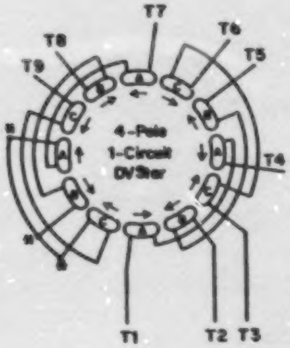
	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
18. Connect a four-pole, three-phase stator for a one circuit wye (Fig. #6)  Fig. #6 Connect FA, FB, and FC together. L1, L2, L3, connect to SA, SB, and SC respectively	A. Develop a three-phase, single circuit Wye connection on the chalkboard Use this to discuss and explain principles of connecting B. Demonstrate 1. Connecting each phase a. Reverse polarity of each phase group at succeeding poles b. Connect B phase opposite in polarity to A and C phase 2. Solder splices and insulate 3. Shape widing with mallet and fiber 4. Secure winding with tie cord 5. Check overhang of winding 6. Varnish and bake winding	A. Discuss principles of three-phase stator connections 1. Polarity of phases 2. Polarity of groups 3. Voltage per group and coil 4. Type connections
19. Test a three-phase stator for grounds, opens, shorts, and reverses after rewinding	A. Demonstrate 1. Use of series lamp tester to test stator for grounds 2. Use of series lamp tester to test for circuit open and then to isolate open 3. Use of internal growler to test for shorts 4. Use of test rotor to test for reverses	A. Review grounds, opens, shorts and reverses 1. Definition 2. Causes 3. Effects 4. Testing methods B. Review the internal growler

20. Assemble and test a three-phase motor after rewinding	A. Discuss importance of checking parts for proper operation before reassembling a rewound motor B. Demonstrate 1. Checking for burrs and high spots on parts 2. Checking the bearings 3. Assembling the motor 4. Checking for excessive end play and free turning 5. Testing for ground 6. Running motor and checking current with an amprobe 7. Running motor and checking for excessive heat or improper sound	A. Display and review the megger 1. Purpose 2. Principle of operation 3. Reading the scale 4. Applications 5. Use in preventative maintenance procedures
21. Connect a four-pole, three-phase stator for one-circuit delta(Fig. #7)  Fig. #7 Connect: FA to SB→L1 FB to SC→L2 SC to SA→L3	A. Explain to students that they will be makings four different connections, using the same stator. However, in actual practice, a stator must be rewound in order to convert it from wye to delta or delta to wye B. Develop a three-phase, single circuit delta connection on the chalkboard. Use this to review principles of connecting, and difference between a wye and delta connection. C. Demonstrate 1. Connecting each phase group and phase circuit as in a wye connection 2. Forming the delta connection from the start and finish leads of the three phases	

TEACHING CONTENT

Tasks

22. Connect a four-pole, three-phase stator for dual-voltage wye



DUAL VOLTAGE STAR CONNECTIONS

Voltage	L1	L2	L3	Tie Together
Low	1-7	2-8	3-9	4-5-6
High	1	2	3	4-7, 5-8, 6-9

Voltage connections for three-phase dual-voltage star terminal

Fig. #8

Development of Skills

A. Develop a three-phase dual-voltage wye-connected stator on chalkboard Use this to trace connections
B. Demonstrate
    1. Connecting phase groups salient
    2. Bringing out as leads end of second group on each phase Mark these leads 4,5,6
    3. Bring out as leads start of each group at third group Mark these leads 7,8,9
    4. Assemble motor
    5. Connect and run on low volts:
       L1 to T1 and T7
       L2 to T2 and T8
       L3 to T3 and T9
       T4, T5, T6, together
    6. Connect and run on high volts
       L1 - T1
       L2 - T2
       L3 - T3
       T4 and T7 together
       T5 and T8 together
       T6 and T9 together

Development of Related Information

A. Review advantages of using higher voltages on electrical systems
B. Review advantage of dual-voltage motors
C. Discuss voltage principles in dual-voltage connections

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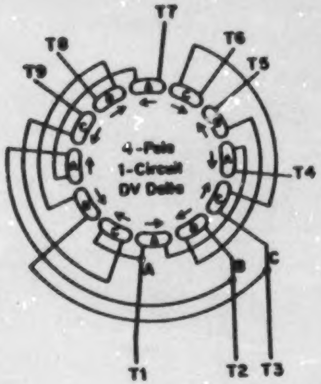
23. Connect a four-pole, three-phase stator for dual voltage delta



DUAL VOLTAGE DELTA CONNECTIONS

Voltage	L1	L2	L3	Tie Together
Low	1-6-7	2-4-8	3-5-9	- - - - -
High	1	2	3	4-7, 5-8, 6-9

Voltage connections for three-phase, dual-voltage delta terminals

Fig. #9

A. Develop a three-phase, dual-voltage delta-connected stator on chalkboard. Use this to trace connections.

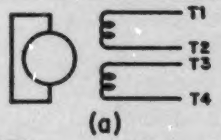
B. Demonstrate
   1. Connecting phase groups salient
   2. Bringing out end of second group of each phase as leads; mark these leads 4,5,6
   3. Bringing out as leads start of each group at third group. Mark these leads 7,8,9
   4. Assemble motor
   5. Connect and run on low volts:
      L1 - T1, T6, T7
      L2 - T2, T4, T8
      L3 - T3, T5, T9
   6. Connect and run on high volts:
      L1 - T1
      L2 - T2
      L3 - T3
      4 and 7 together
      5 and 8 together
      6 and 9 together

A. Discuss voltage and current formulas for wye and delta connections
   1. Wye:
      a. EL = Ep x 1.73
         IL = Ip

   2. Delta:
      EL = IL
      IL = Ip x 1.73

B Explain phase angle and its relationship to 1.73 ($\sqrt{3}$)

Tasks	TEACHING CONTENT Development of Skills	 Development of Related Information
24. Disassemble, repair, and reassemble repulsion motors	Demonstrate 1. Marking end shields 2. Removing pulley and key 3. Removing end shields 4. Checking bearings 5. Checking armature winding and commutator 6. Turning down commutator, if necessary 7. Removing and cleaning centrifugal assembly, and replacing necklace, barrel, or brushes, if necessary 8. Reassembling centrifugal assembly and checking operation 9. Assembling motor 10. Running motor and checking current 11. Running motor and checking for overheating or improper sounds	A. Discuss repulsion motors 1. Definition 2. Principle of operation 3. Reversing 4. Three types 5. Dual-voltage operation 6. Applications 7. Sizes



VOLTAGE	L1	L2	Join
High	T1	T4	T2-T3
Low	T1-T3	T2-T4	- - -

(b)

Diagram for dual-voltage repulsion-start induction and repulsion-induction motors: (a) lead identification, (b) dual-voltage connections. Reversal is by shifting brushes

Fig. #10

25. Disassemble, repair, and reassemble a capacitator start motor

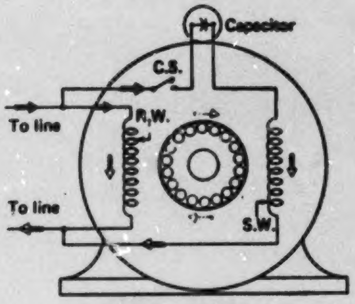


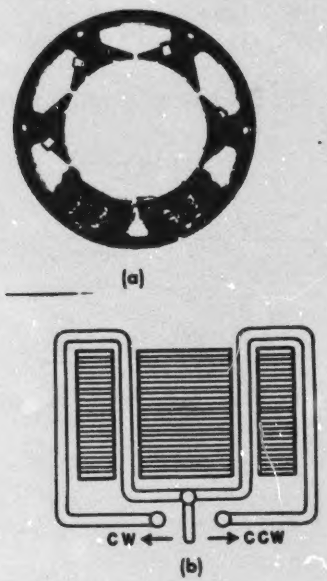
Fig. #11

Single voltage capacitor-start motor connected for clockwise rotation. Note direction of current in windings

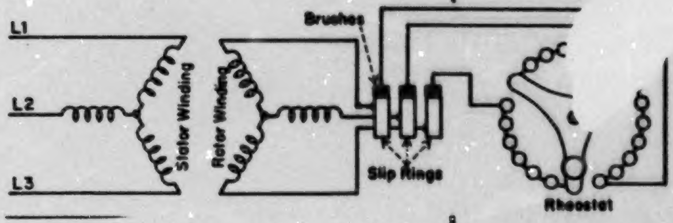
Demonstrate

1. Marking end shields
2. Removing pulley and key
3. Removing end shields
4. Checking and replacing bearings
5. Checking and replacing the centrifugal switch
6. Checking and replacing the capacitor
7. Checking the windings
8. Assembling the motor
9. Running motor and checking current
10. Running motor and checking for overheating or improper sound

A. Discuss capacitor start motors
    1. Definition
    2. Construction
    3. Advantage over split phase motors
    4. Sizes
    5. Application
    6. Circuitry (Fig. #11)
    7. Capacitor theory
B. Stress safety hazards when discharging a capacitor

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
26. Disassemble, repair, and reassemble shaded-pole motors  (a) Shaded-pole stator frame showing short-circuited shading bands on poles. (b) Illustration of principles of shaded-pole reversing system Fig. #12	Demonstrate 1. Disassembling 2. Checking bearings 3. Checking shaded coil 4. Checking windings 5. Reassembling 6. Running motor and checking for correct current, overheating, and sound	A. Discuss shaded-pole motors 1. Definition 2. Construction 3. Sizes 4. Principle of operation 5. Reversing 6. Applications

27. Disassemble, repair, and reassemble wound-rotor, 3-phase motors



Power wiring connections for a wound-rotor motor

Fig. #13

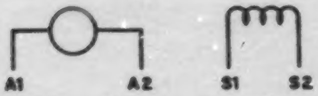
A. Display the wound-rotor motor with secondary resistance control (Y-box); discuss its operation

B. Demonstrate
   1. Checking brushes and slip rings
   2. Dismantling motor
   3. Checking bearings
   4. Checking the rotor
   5. Checking the stator
   6. Checking the Y-box
   7. Assembling motor
   8. Setting the brushes
   9. Running motor connected to Y-box
   10. Checking for correct current, overheating, and correct sound

A. Discuss the three phase wound-rotor motor
   1. Definition
   2. Construction
      a. end shields
      b. stator
      c. rotor with Y-box
   3. Advantages
   4. Disadvantages

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
28. Turn down slip rings on wound rotor motors	A. Discuss fact that slip rings can become pitted or grooved B. Demonstrate 1. Placing rotor in chuck and center of tail stock 2. Running lathe at medium speed with rotation toward operator; using pencil to check for true turning 3. Setting tool bit slightly below center of slip rings 4. Taking small cuts until rings are smooth 5. Touching up rings with smooth sand paper 6. Removing rotor from lathe	A. Discuss the three phase wound rotor motor 1. Theory of operation 2. Characteristics 3. Reversing 4. Method of starting B. Discuss the lathe 1. Parts: check, tail stock with center, carriage, tool holder, tool post, tool bit 2. Lathe safety a. Need for goggles b. Clean and clear work surfaces and floor areas

29. Disassemble, repair, and reassemble universal motors



(a)

Rotation	L1	L2	Join
CCW	A1	S2	S1-A2
CW	A1	S1	A2-S2

(b)

Diagrams for reversible universal series motors: (a) lead identification, (b) rotation connections

Fig. #14

A. Display a universal motor and compare it to a D.C. series motor

B. Demonstrate
   1. Disassembling motor
   2. Checking bearings and brushes
   3. Checking fields
   4. Checking armature
   5. Turning down commutator, if necessary
   6. Reassembling motor
   7. Running motor and checking current, amount of sparking and overheating

A. Discuss universal motors
   1. Definition
   2. Sizes
   3. Applications
   4. Characteristics
   5. Circuitry
   6. Reversing

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
30. Change bearings on A.C. motors	A. Demonstrate replacement of a sleeve bearing 1. Removing with bearing driver and hammer,or: 2. Removing with bearing driver and arbor press 3. Installing with bearing driver and hammer,or: 4. Installing with bearing driver and arbor press 5. Reaming bearing to proper size 6. Checking shaft in bearing for free turning B. Demonstrate replacement of a ball bearing 1. Removing on arbor press or: 2. Removing with bearing puller 3. Installing with tubing and hammer or: 4. Installing with tubing and arbor press 5. Heating bearing and freezing shaft on large machines	Discuss sleeve and ball bearings 1. Purpose 2. Types 3. Lubrication 4. Problems

Unit V: A.C. Motor Controls

Level Three: Motors and Controls
Suggested Time: *200 Hours / 300 Periods*

Performance Objectives

Upon completion of this unit the student will be able to:

- Connect a three-phase, squirrel-cage motor to a three-pole safety switch and run motor in both directions.
- Connect a three-phase, squirrel-cage motor to an across-the-line starter, controlled from two start buttons and one stop button, and a drum switch to reverse rotation.
- Connect a three-phase, squirrel-cage motor to a magnetic reversing starter and a forward-reverse-stop station with electrically interlocked push buttons.
- Connect a repulsion motor to an across-the-line magnetic starter operated from two start-stop stations.

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
1. Connect a three-phase squirrel-cage motor to a three-pole safety switch. Run motor in both directions	A. Display a three-phase squirrel motor; briefly describe its operation B. Display a safety switch and describe its purpose C. Explain how a three-phase squirrel-motor is reversed D. Develop job circuit on chalkboard E. Demonstrate mounting of equipment F. Demonstrate job wiring procedures G. Test job for proper operation a. Run motor clockwise and counterclockwise	A. Discuss motor control 1. Meaning 2. Controller functions a. Start b. Stop c. Accelerate d. Decelerate e. Regulate speed f. Plug g. Jog h. Brake i. Reverse j. Protection 3. Types of motor control a. Manual b. Semi-automatic c. Automatic
2. Connect a three-phase squirrel-cage motor using a manual "across-the-line" starter	A. Display a manual starter; illustrate its internal wiring and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring procedures E. Test job for proper operation	A. Discuss manual starters 1. Construction 2. Internal wiring 3. Application limitations

3. Connect a three-phase, squirrel-cage motor using a manual starter and a double-pole double-throw switch to reverse rotation

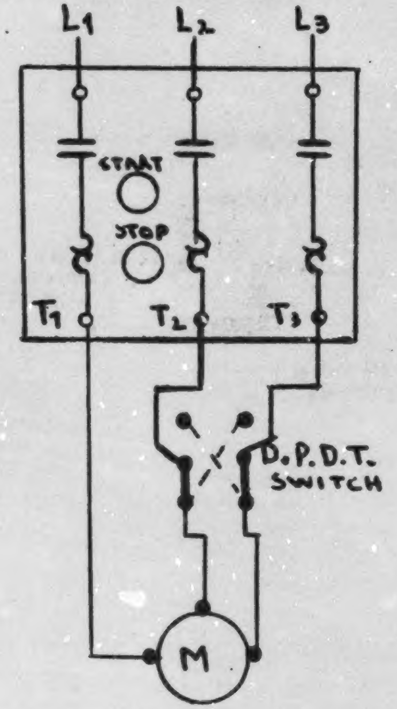
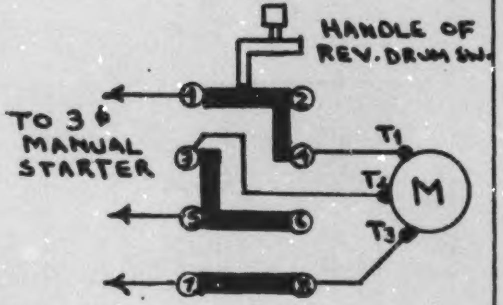


Fig. #1

A. Display a double-pole, double-throw reversing switch, illustrate its circuitry and demonstrate its operation
B. Develop job circuit on blackboard
C. Review mounting of equipment
D. Demonstrate job wiring procedures
E. Test job for proper operation in both directions

A. Discuss three-phase, squirrel-cage induction motors
   1. Definition
   2. Advantages as compared to single-phase motors
   3. Construction
   4. Principle of operation
   5. Reversing

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
4. Connect a three-phase, squirrel-cage motor using a manual starter and a drum switch for reversing rotation  HANDLE OF REV. DRUM SW. TO 3φ MANUAL STARTER 1 2 3 4 5 6 7 8 T1 T2 T3 M Fig. #2	A. Display a drum switch; illustrate its internal wiring, and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring of drum switch E. Test job for proper operation in both directions	A. Discuss drum switches 1. Advantages 2. Applications 3. Types 4. Circuitry

5. Connect a three-phase, squirrel-cage motor controlled by an across-the-line magnetic starter operated from a start-stop pushbutton station

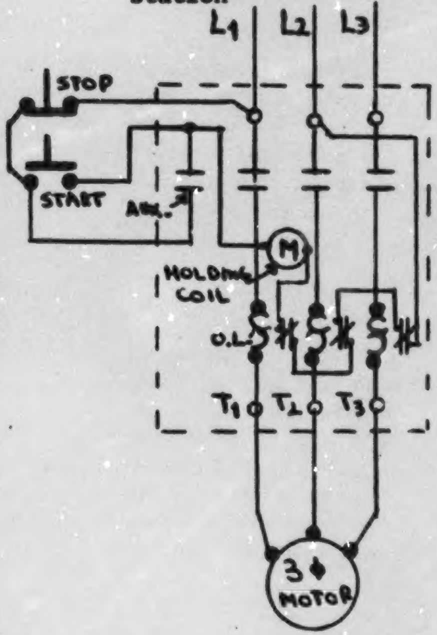


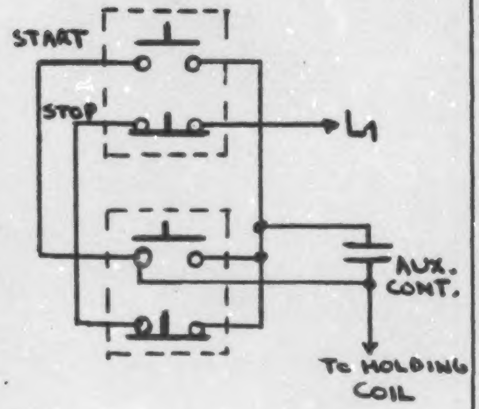
Fig. #3

A. Display an across-the-line magnetic starter; illustrate its circuitry and demonstrate its operation
B. Develop job circuit on chalkboard
C. Demonstrate mounting of magnetic starter
D. Demonstrate job wiring of magnetic starter
E. Test job for proper operation from the control station

A. Discuss magnetic starters
   1. Advantages and over manual starters
   2. Construction
   3. Internal wiring
   4. Compare A.C. starters to the D.C. type

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
6. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic starter, operated from a short-stop station, and a drum switch to reverse rotation	A. Review operation of magnetic starters and drum switches B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation in both directions from control station	A. Discuss full-voltage starting 1. Definition 2. Applications 3. Disadvantages B. Discuss pushbutton control stations 1. Purpose 2. Types 3. Applications
7. Connect a squirrel-cage three-phase motor to an across-the-line starter, controlled from two start buttons and one stop button, and a drum switch to reverse rotation	A. Illustrate and explain connection of start buttons when connected in multiple B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation in both directions from both stations	A. Discuss motor overloading 1. Types: mechanical or electrical 2. Protection of manual starters 3. Protection on magnetic starters 4. Meaning and effect of single phasing

8. Connect a three-phase, squirrel-cage motor to an across-the-line starter, controlled from a start-stop station and an emergency stop station	A. Discuss reason why a motor installation may have several emergency stop buttons B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation from both stations	A. Discuss speed of three-phase induction motors 1. Synchronous speed 2. Rotor speed 3. Slip 4. Formula for synchronous speed: $S= \frac{Fx60}{P_p}$

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
9. Connect a three-phase, squirrel-cage motor to an across-the-line starter, operated from a start-stop stations, and a drum switch for reversing  Fig. #4	A. Develop job circuit on chalkboard B. Review mounting of equipment C. Review job wiring procedures D. Test job for proper operation in both directions from both control stations	A. Discuss motor protection 1. Types: short circuit and motor running 2. Code regulations for overload protection 3. Types of thermal relays 4. Operation of the heater in conjunction with the relay

10. Connect a three-phase, squirrel-cage motor to an across-the-line starter, operated from a start-jog-stop push-button station

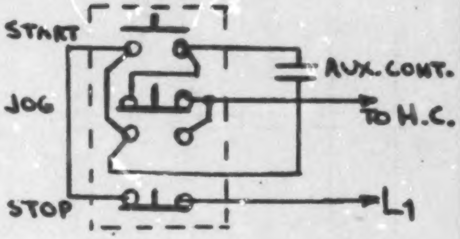
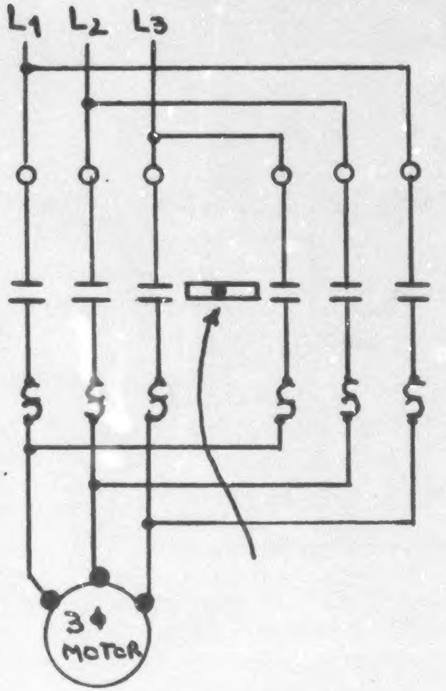


Fig. #5

A. Display a jog button, illustrate its circuitry, and demonstrate its operation
B. Develop job circuit on chalkboard
C. Review job mounting procedures
D. Demonstrate job wiring for a start-jog-stop station
E. Test job for proper operation from the control station

A. Discuss jogging
   1. Definition
   2. Applications
   3. Construction of jog buttons
   4. Connection in a circuit
   5. Types of jog circuits

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
11. Connect a three-phase, squirrel-cage motor to a manually operated reversing starter with a mechanical interlock  Fig. #6	A. Display a manual reversing starter; illustrate its circuitry and demonstrate its operation B. Develop job circuit on blackboard C. Demonstrate mounting of heavy equipment D. Demonstrate job wiring for a manual reversing starter E. Test job for proper operation in both direction from the starter Demonstrate how the mechanical interlock works	A. Discuss manual reversing starters 1. Definition 2. Limitations 3. Internal wiring 4. Overload protection 5. Mechanical interlocking

12. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic reversing starter, operated from a forward-reverse-stop push button station

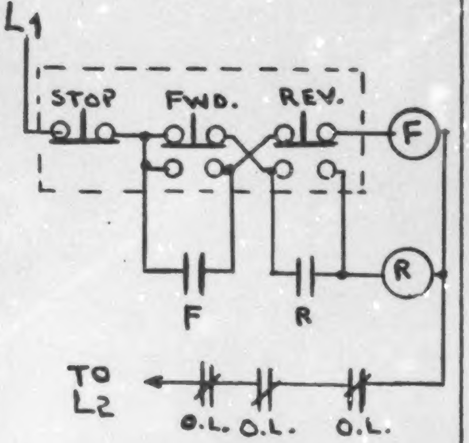
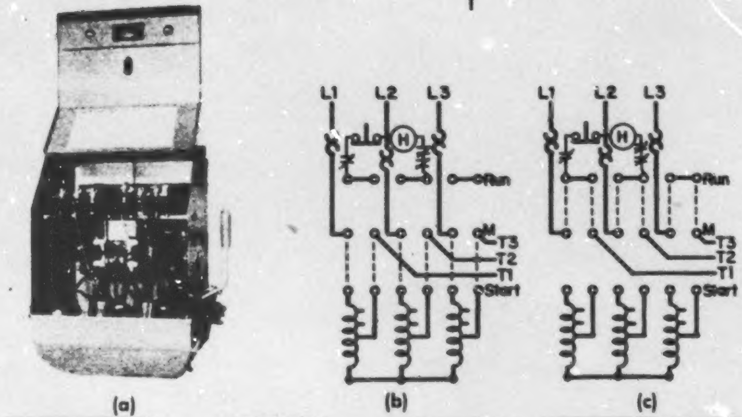


Fig. 57

A. Display a magnetic reversing starter; illustrate its circuitry and demonstrate its operation
B. Develop job circuit on chalkboard
C. Review job mounting procedures
D. Demonstrate job wiring for a magnetic reversing starter
E. Test job for proper operation in both directions; demonstrate interlocking.

A. Discuss magnetic reversing starters
   1. Definition
   2. Advantages compared with the manual type
   3. Construction
   4. Internal wiring
   5. Types of interlocking
   6. Type of control stations

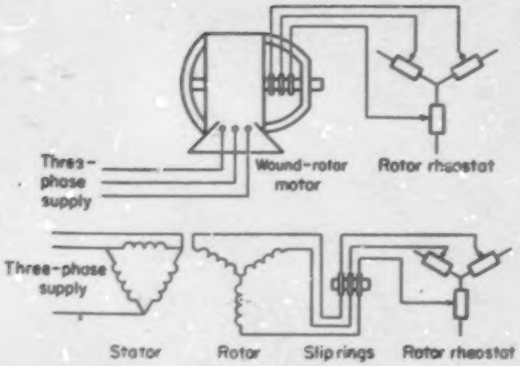
	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
13. Connect a three-phase, squirrel-cage motor to a manual type autotransformer compensator and an additional stop button for emergency operation	A. Display a manual compensator; illustrate its circuitry and demonstrate its operation B. Develop installation of manual compensator C. Demonstrate installation of manual compensator D. Demonstrate job wiring of manual compensator E. Test job for proper operation	A. Discuss autotransformer type compensators 1. Purpose 2. Advantage over primary resistance starter 3. Autotransformer theory 4. Construction 5. Operation 6. Purpose of oil



(a) Autotransformer starter.
(b) Typical circuit diagram of autotransformer in starting.
(c) Autotransformer circuits for running.

Fig. #8

14. Connect a three-phase, wound-rotor inductor motor to a secondary resistance control (Y-box) and a manual starter for on or off operation of the motor


Three-phase supply
Wound-rotor motor
Rotor rheostat
Three-phase supply
Stator
Rotor
Slip rings
Rotor rheostat

Circuits of a wound-rotor induction motor

Fig. #9

A. Display a wound-rotor induction motor with secondary resistance control; illustrate its circuitry and describe its operation
B. Develop job circuit on chalkboard
C. Demonstrate mounting of heavy equipment
D. Demonstrate job wiring of motor and controller
E. Test job for proper operation
    1. Start motor with all resistance in circuit and bring to desired speed

A. Discuss wound rotor induction motors
    1. Definitions
    2. Applications
    3. Construction
    4. Auxiliary equipment
    5. Advantages
    6. Disadvantages
    7. Circuitry

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
15. Connect a three-phase, squirrel-cage motor to an across-the-line starter operated from two start-stop-jog stations	A. Review purpose and construction of jog buttons B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for two start-stop-jog stations E. Test job for proper operation from both control stations	A. Discuss national electric code current rating for three-phase motors (Table 430-150) 1. Purpose of table 2. Discuss several examples for various horsepower and voltage ratings 3. Have students use table

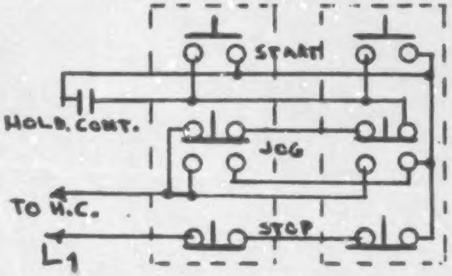


Fig. #10

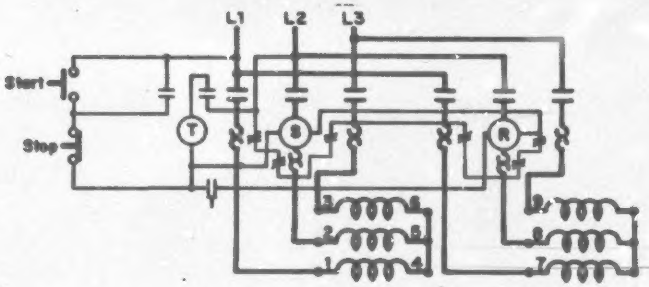
16. Connect a three-phase, wound-rotor induction motor to a secondary resistance control, and a magnetic starter operated from a start-stop station	A. Review the wound-rotor motor and secondary resistance controller B. Develop job circuit on chalkboard C. Review installation of heavy equipment D. Review job wiring procedures E. Test job for proper operation from control station	A. Discuss wound-rotor induction motors 1. Principle of operation 2. Starting torque 3. Efficiency at various speed 4. Speed regulation 5. Power factor
17. Connect a three-phase, wound-rotor induction motor to a secondary resistance control, an across-the-line starter operated from a start-stop station, and a drum switch to reverse rotation	A. Discuss code regulations for controllers (N.E.C., Article 430:G) 1. General provisions 2. Design 3. Location 4. Speed limitation B. Discuss code for wound rotor secondaries (N.E.C., Article 430-23)	A. Develop job circuit on chalkboard B. Review mounting of heavy equipment C. Review job wiring procedures D. Test job for proper operation 1. Start motor with all resistance in rotor 2. Operate control station 3. Run motor in both directions

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
18. Connect a dual-voltage, wye-connected squirrel-cage motor to an across-the-line starter, operated from a start-stop station, and a drum switch to reverse rotation. Step 1. Connect motor leads for 220V, and operate in both directions Step 2. Connect motor leads for 440V, and operate in both directions Note: If 440V is not available, motor may be connected to 220V, in which case it will run but with reduced torque	A. Display a nine-lead, dual-voltage motor; illustrate its internal circuit, and demonstrate how connections are made B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring procedures E. Test job for proper operation 1. Connect motor for low volts, and run in both directions 2. Reconnect motor for high volts, and run in both directions	A. Discuss advantages of using higher voltages for electrical systems B. Discuss advantage of dual-voltage motors C. Explain how connections are made on nine lead, dual-voltage motors

19. Connect a three-phase, squirrel-cage motor to a magnetic reversing starter, operated from two forward-reverse-stop stations	A. Review construction and operation of magnetic reversing starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for two forward-reverse-stop stations E. Test job for proper operations from both control stations	A. Discuss code regulations for motor circuit conductors (N.E.C., Article 430:B) 1. General provisions 2. Single motor 3. Wound-rotor secondary 4. Several motors 5. Motors and other loads 6. Feeder demand factor

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information

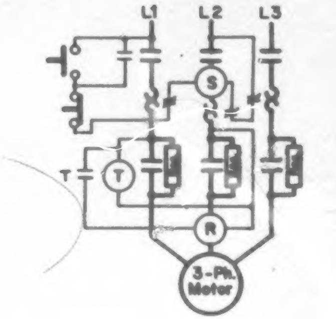
20. Connect a three-phase, squirrel-cage motor to a part-winding (increment) magnetic starter operated from a start-stop station. Note: A dual-voltage, wye-connected motor may be used	A. Display a part-winding magnetic starter; illustrate its internal circuitry and describe its operation
	B. Develop job circuit on chalkboard
	C. Demonstrate installation of heavy equipment
	D. Demonstrate job wiring for an increment starter
	E. Test job for proper operations
	    1. Note operation of timer to give two-step starting
		A. Discuss increment starting
		    1. Purpose
		    2. Construction of part-winding starters
		    3. Type motors used
		    4. Internal circuitry
		    5. External wiring
		    6. Torque characteristics



Typical part-winding starting system control, starter, and motor connections

Fig. #11

21. Connect a three-phase, squirrel-cage motor to a magnetic primary resistance starter operated from a start-stop station



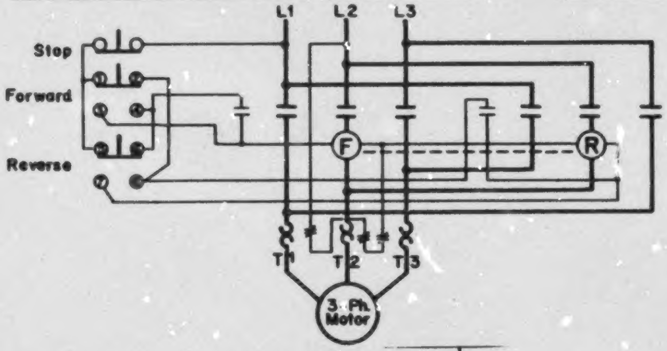
Typical wiring plan of primary resistance starter

Fig. #12

A. Display a primary resistance starter; illustrate its internal wiring and describe its operation
B. Develop job circuit on chalkboard
C. Demonstrate mounting of starter
D. Demonstrate job wiring for primary resistance starter
E. Test job for proper operations
   1. Note operation of timer to give two-step starting

A. Discuss primary resistance starters
   1. Purpose
   2. Construction
   3. Internal circuitry
   4. Timing
   5. Application

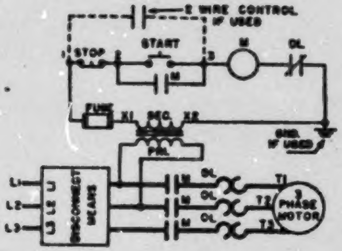
	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
22. Connect a three-phase, squirrel-cage motor to a magnetic reversing starter and a forward-reverse-stop station with electrically interlocked pushbuttons	A. Develop job circuit on chalkboard B. Review mounting of equipment C. Demonstrate job wiring for pushbutton interlocking D. Test job for proper operation E. Demonstrate interlocking of pushbutton	A. Discuss types of interlocking used in reversing starters 1. Mechanical 2. Pushbutton interlocking 3. Auxiliary contact interlocking B. Discuss squirrel-cage rotor construction 1. Type winding 2. Double-bar type 3. Skewing 4. Slip and torque characteristics



Typical circuit arrangement for magnetic reversing a three-phase motor

Fig. #13

23. Connect a three-phase, squirrel-cage motor to a primary resistance starter, operated from a start-stop station, and a drum switch to reverse rotation	A. Review construction and operation of primary resistance starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation in both directions from control station	A. Discuss meaning of open transition and closed transition in magnetic starters B. Discuss primary-resistance starters 1. Multi-step starting types 2. Advantage of closed transition 3. Advantage of smooth motor acceleration 4. Advantage of minimal line disturbance
24. Connect a three-phase, squirrel-cage motor to a combination starter operated from a start-stop station	A. Display a combination starter; illustrate its internal wiring and demonstrate its operation B. Develop job circuit on chalkboard C. Review installation of heavy equipment D. Demonstrate job wiring for combination starters E. Test job for proper operation from the control station	A. Discuss the advantages of combination starters 1. Greater safety 2. Ease of installation 3. Space conservation B. Discuss the advantage of using a combination starter equipped with a control transformer

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
25. Connect a three-phase, squirrel-cage motor to a combination starter with a control transformer, operated from a start-stop station  2 WIRE CONTROL IF USED STOP START 1 2 3 M OL M FUSE X1 SEC. X2 PRI. GND. IF USED L1 L2 L3 L1 L2 L3 DISCONNECT MEANS M OL M OL M OL T1 T2 T3 3 PHASE MOTOR Combination Starter Fig. #14	A. Display a combination starter with a control transformer and discuss its advantage B. Develop job circuit on chalkboard C. Review job mounting procedures D. Review job wiring procedures E. Test job for proper operation from the control station	A. Discuss the meaning of items on name plate of three-phase motors 1. Volts 2. AMPS 3. R.P.M. 4. Horsepower 5. Temperature 6. Duty 7. Code letter 8. Type 9. Phase 10. Cycles 11. Frame 12. Service factor 13. Design 14. Model 15. Serial 16. Manufacturer's name

26. Connect two three-phase, squirrel-cage motors for sequence control. Each motor is operated by a magnetic starter controlled from its own push-button station. Wire the circuit so that motor #2 cannot be started unless motor #1 is running

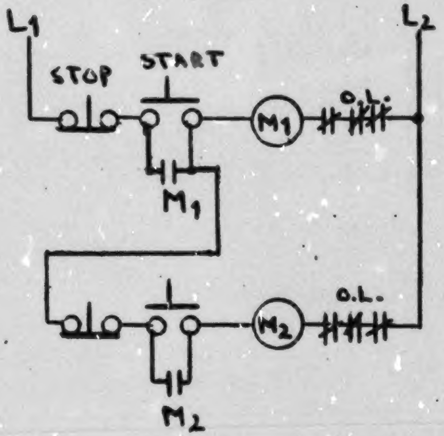
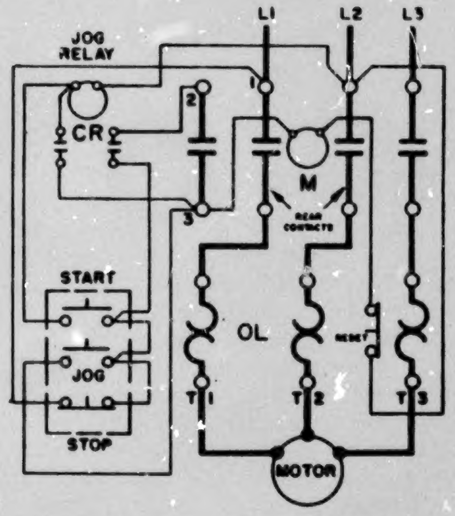


Fig. #15

A. Discuss application for sequence starting
B. Develop job circuit on chalkboard
C. Review mounting of equipment
D. Demonstrate job wiring for sequence starting
E. Test job for proper operation
    1. Run motor #1
    2. Run motor #2
    3. Demonstrate that #2 cannot be started without #1 running
    4. Demonstrate that shutting down #1 causes #2 to shut down also

A. Discuss sequence starting
    1. Definition
    2. Purpose
    3. Method of accomplishment
    4. Applications
    5. Circuitry

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
27. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic starter operated from a start-jog-stop station with a jog-relay attachment  JOG RELAY L1 L2 L3 CR 1 2 3 M REAR CONTACTS START JOG STOP OL RESET T1 T2 T3 MOTOR A jog-relay connected to a magnetic switch Fig. #16	A. Display a jog-relay attachment; illustrate its circuitry and describe its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring of jog-relay E. Test job for proper operation	A. Discuss the jog-relay attachment 1. Safety of operation 2. Circuitry B. Discuss code regulations for motor and branch circuit overload protection (N.E.C., Article 430:C)

28. Test for and identify the nine leads on an unmarked dual voltage wye-wound three-phase, starter

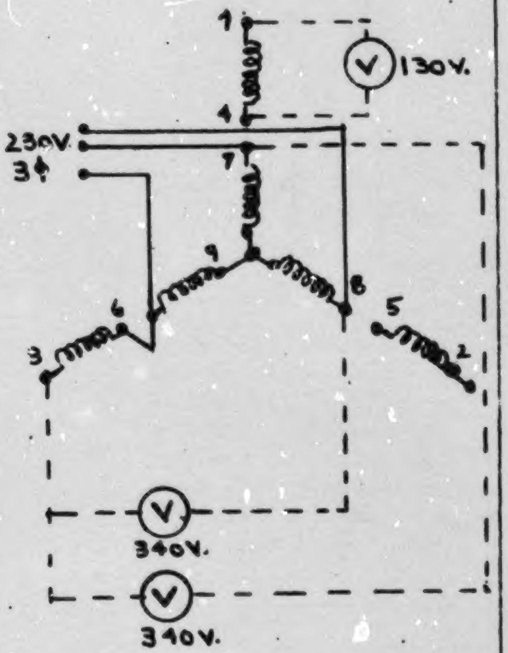
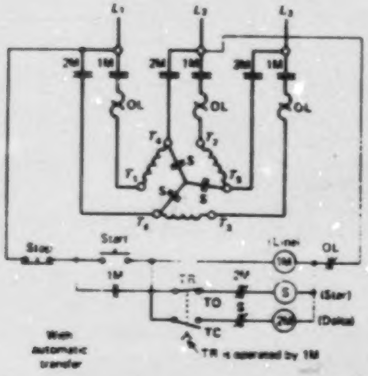


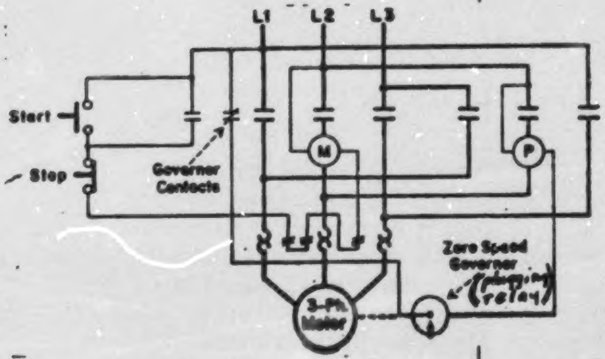
Fig. #17

A. Demonstrate:
    1. How to identify that it is wye connected (must have one 3-lead ckt, and three 2-lead ckts)
    2. How to test for leads of each set of coils
B. With a chalkboard drawing of Fig. #17 discuss voltage relationship between coils
C. Demonstrate testing the coils to obtain voltages indicated in Fig. #17

A. Discuss induction motor braking
    1. Dynamic braking
        a. Principle of operation
        b. Equipment used
    2. Regenerative braking
        a. Principle of operation
        b. Equipment used
B. Discuss three phase wye transmission systems
    1. How generated
    2. Applications
    3. Advantages
    4. Circuitry

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
29. Connect a three-phase, squirrel cage motor to a wye-delta magnetic starter, operated from a start-stop station. Motor will start as a wye-connected and run as a delta-connected unit  L1 L2 L3 2M 1M 2M 1M 2M 1M OL OL OL T4 T2 T1 S T5 S S T6 T3 Stop Start (Line) 1M OL 1M TR 2M S (Start) TO S 2M (Delta) TC With automatic transfer TR is operated by 1M Wye-delta magnetic starter Fig. #18	A. Display a wye-delta starter; illustrate its internal wiring, and describe its operation B. Develop job circuit on chalkboard C. Review mounting of heavy equipment D. Demonstrate job wiring for a wye-delta starter E. Test job for proper operation in start and run positions	A. Discuss wye-delta starters 1. Purpose 2. Construction of starter 3. Internal circuitry 4. Type motor used 5. Wye-delta starting with a triple pole-double throw switch

30. Connect a three-phase, squirrel-cage motor to a controller with a plugging relay for braking, controlled from a start-stop s station


L1
L2
L3
Start
Stop
Governor Contacts
M
P
Zero Speed Governor (plugging relay)
3-Ph. Motor

Automatic plugging starter for a three-phase motor

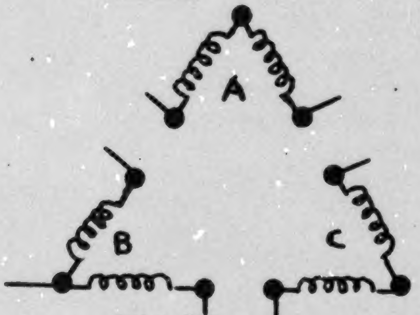
Fig. #19

A. Display a plugging relay, describe its purpose, and demonstrate how it is mounted on a motor
B. Explain that a reversing magnetic starter must be used for plugging
C. Develop job circuit on chalkboard
D. Review mounting of equipment
E. Demonstrate job wiring for a plugging system
F. Test job for proper operation

A. Discuss induction motor braking
    1. Plugging
        a. Principle of operation
        b. Equipment used
    2. Mechanical braking
        a. Principle of operation
        b. Equipment used

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
31. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic starter, operated from a start-stop station with a pilot light to indicate when the motor is running	A. Display a control station equipped with a pilot light; illustrate circuitry, and describe operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring procedures for a pilot light circuit E. Test job for proper operation	A. Discuss use of pilot lights in motor installations 1. Indicate motor on 2. Indicate motor off 3. Safety purposes 4. Methods of connection B. Discuss acceleration control of A.C. motors 1. Manual control 2. Definite-time control 3. Current-limit control 4. Slip-frequency control

32. Test for and identify the nine leads of an unmarked dual-voltage delta-wound, three-phase stator



(Fig #20

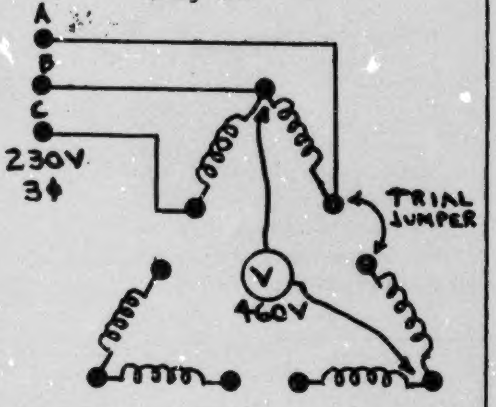


Fig. #21

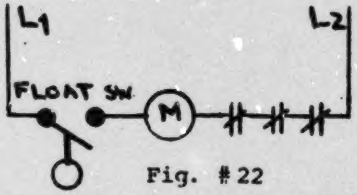
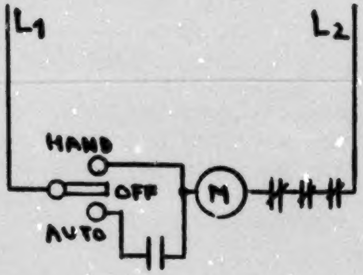
Demonstrate

A. How to identify leads in group A, B, and C by use of an ohmmeter or bell battery tester and to label each lead. (Fig. #20)

B. Apply 3 Φ 230V to the three leads in one group; motor will run unloaded (Fig. #21)
Attach trial jumper as in Fig. #21
Test voltage, as in Fig. #21 If reading is about 460V, trial jumper is correct. If not, repeat process with other leads
Repeat the process until a delta is formed, and make trial jumpers permanent

A. Discuss three-phase delta transmission systems
   1. How generated
   2. Applications
   3. Advantage
   4. Circuitry

B. Discuss wye and delta-connected motors:
   1. Explain that either type can be used on either type service
   2. Briefly describe how to convert one type with regard to turns and wire size changes

	TEACHING CONTENT	
Tasks	**Development of Skills**	**Development of Related Information**
33. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic starter operated from a float switch  Fig. #22	A. Display a float switch; illustrate its circuitry and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a float switch circuit E. Test job for proper operation from float switch	A. Discuss two-wire control of three-phase motors 1. Applications 2. Circuitry 3. Types a. Pressure switches b. Float switches c. Thermostats d. Limit switches e. Photo cells f. Timers g. Electronic devices
34. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic starter operated from a hand-off-auto selector switch and a limit switch  Fig. #23	A. Display a hand-off-auto switch; illustrate its circuitry and describe its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a hand-off auto switch circuit E. Test job for proper operation in three positions of switch	A. Discuss hand-off-auto switches 1. Purpose 2. Applications 3. Positions a. Hand-motor runs continuously b. Off-motor does not run c. Auto-motor runs whenever two-wire control device closes

35. Connect a three-phase, squirrel-cage motor to an across-the-line starter operated from a start-stop station with a jog-run selector switch

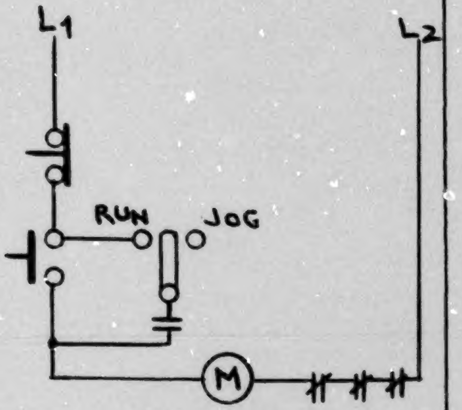


Fig. #24

A. Display jog-run selector switch; illustrate its circuitry, and describe its circuitry operation

B. Develop job circuit on chalkboard

C. Review mounting of equipment

D. Demonstrate job wiring job-run selector switch circuit

E. Test job for proper operation in both positions of selector switch

F. Emphasize anti-hangup feature of this system

A. Discuss job selector switching
   1. Purpose
   2. Circuitry

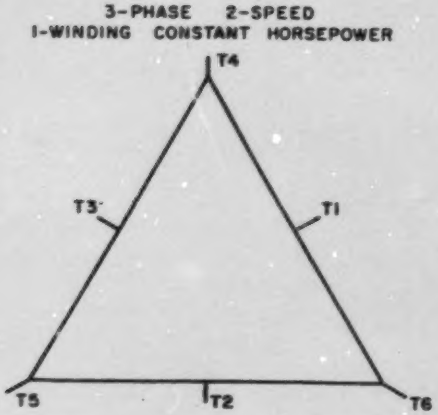
B. Discuss how to calculate efficiency of 3 phase induction motors
   1. Definition
   2. Formula:

$$\text{EFF} = \frac{\text{Watts Output}}{\text{Watts Input}} = \frac{\text{H.P. x 746}}{W_1 + W_2}$$

   3. Work out examples

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
36. Connect a three-phase, squirrel-cage motor to an across-the-line magnetic reversing starter operated from a forward run-forward-jog-reverse run-reverse jog-stop station	A. Display the switch used on this job; illustrate circuitry and describe circuit operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for the control station being used E. Test job for proper operation from five positions of control station	A. Discuss applications for the circuit being performed B. Discuss how to calculate power factor of three-phase induction motors 1. Definition 2. Formula: $\text{P.F.} = \frac{W_1 + W_2}{3 \times E_L \times I_L}$ 3. Work out examples
37. Connect a three-phase, squirrel-cage motor to a combination starter operate from two start-stop stations	A. Review construction and advantages of combination starters B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring for a circuit with a combination starter E. Test the job for proper operation from both control stations	A. Discuss losses in three-phase motors 1. Copper losses in windings 2. Fixed losses a. Friction b. Windage c. Iron

38. Connect a two-speed, constant horsepower three-phase, squirrel-cage motor controlled by a two-speed constant horsepower consequent starter operated from a fast-slow-stop station.



SPEED	L1	L2	L3	OPEN	TOGETHER
LOW	T1	T2	T3	————	T4, T5, T6
HIGH	T6	T4	T5	ALL OTHERS	————

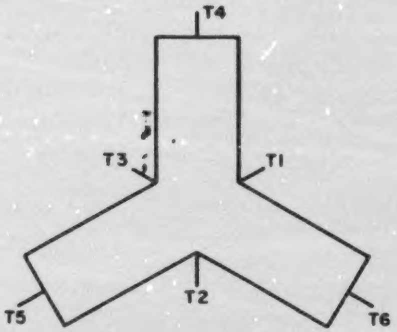
Fig. #25

A. Display the motor, starter, and control station used for the job. Describe the operation of each
B. Discuss connections for fast and slow speeds (Fig. #25)
C. Develop job circuit on chalkboard
E. Demonstrate job wiring for the circuit being performed
Test job for proper operation from control station

A. Discuss consequent connected motors and starters
  1. Purpose
  2. Type motor connection
  3. Types
B. Discuss constant horsepower consequent motors and starters
  1. Purpose
  2. Motor winding connections
  3. Controller design

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
39. Connect a two-speed, constant-torque, three-phase squirrel-cage motor, controlled by a two-speed, constant-torque controller, operated from a fast-slow-stop station	A. Display the motor, starter, and control station used for the job Describe the operation of each B. Discuss connections for fast and slow speeds (Fig. #26) C. Develop job circuit on chalkboard D. Review mounting of heavy equipment E. Demonstrate job wiring for the circuit being performed F. Test job for proper operation from the control station	A. Review consequent connected motors and starters B. Discuss constant torque consequent motors and starters 1. Purpose 2. Motor winding connections 3. Controller design

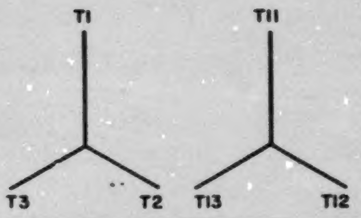
3-PHASE 2-SPEED
1-WINDING CONSTANT TORQUE



SPEED	L1	L2	L3	OPEN	TOGETHER
LOW	T1	T2	T3	ALL OTHERS	———
HIGH	T6	T4	T5	———	T1, T2, T3

Fig. #26

40. Connect a two-speed, two winding, three-phase, squirrel-cage motor controlled by a two-winding, full-voltage starter operated from a fast-slow-stop station



SPEED	L1	L2	L3	OPEN
LOW	T1	T2	T3	ALL OTHERS
HIGH	T11	T12	T13	ALL OTHERS

Connections for three-phase, two-speed, two-winding (separate winding) start

Fig. #27

A. Display the motor, starter, and control station used for job
Describe the operation of each

B. Discuss connections for fast and slow speeds (Fig. #27)

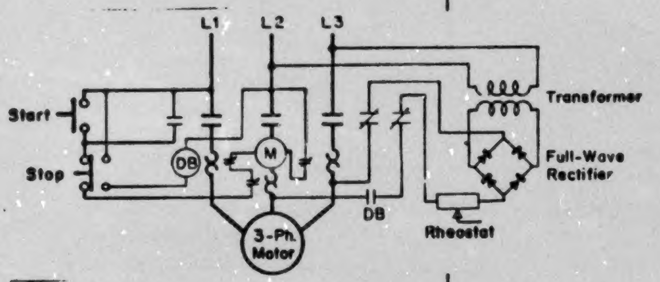
C. Develop job circuit on chalkboard

D. Review mounting of heavy equipment

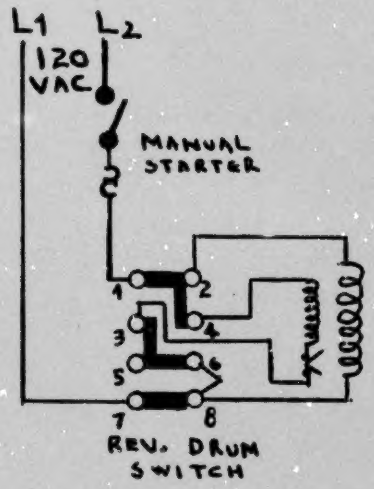
E. Demonstrate job wiring for circuit being performed

F. Test job for proper operation from the control station

A. Discuss two-speed, two-winding, three-phase motors and starters
   1. Purpose
   2. Type motor winding
   3. Controller design

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
41. Connect a three-phase, squirrel-cage motor to a starter designed for dynamic braking  L1 L2 L3 Start Stop DB M 3-Ph. Motor DB Transformer Full-Wave Rectifier Rheostat Across-the-line starter equipped for variable dynamic braking of a three-phase induction motor Fig. #28	A. Display a dynamic braking system using rectifiers for D.C. excitation Illustrate its circuitry and describe its operation B. Develop job circuit on chalkboard C. Review mounting of heavy equipment D. Demonstrate job wiring for a dynamic braking system E. Test job for proper operation	A. Discuss dynamic braking 1. Purpose 2. Principle of operation 3. D.C. excitation from separate source or through rectifiers 4. Circuitry

42. Connect a three-phase, wound-rotor induction motor to an autqmatic 2-step resistance starter operated from a start-stop station	A. Display a two-step resistance starter for a wound-rotor motor; illustrate its circuitry, and describe its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring of the starter E. Test job for proper operation 1. Start motor with all resistance in 2. Bring motor to desired speed	A. Review wound-rotor induction motors and secondary resistance controllers B. Review advantages of two-step starting on three-phase motors
43. Connect a three-phase, squirrel-cage motor to a combination starter with a control transformer operated from two start-stop stations and a drum switch to reverse rotation	A. Review construction and advantages of combination starters equipped with a control transformer B. Develop job circuit on chalkboard C. Review mounting of equipment D. Review job wiring procedures E. Test job for proper operation in both directions from two control stations	A. Discuss problems which occur in magnetic controllers. Discuss procedures for following symptoms 1. Motor does not start when main contacts close 2. Main contacts open when start button is released

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
44. Connect a split-phase motor to a manual starter, and run in both directions	A. Display a split-phase motor and demonstrate its operation B. Review manual starters C. Develop job circuit on chalkboard D. Review mounting of equipment E. Demonstrate job wiring for a split-phase motor circuit F. Test job for proper operation 1. Interchange starting winding leads to reverse rotation	A. Discuss split-phase motors 1. Definition 2. Sizes 3. Applications 4. Main parts a. Rotor b. Stator c. Centrifugal device d. End shields
45. Connect a split-phase motor to a manual starter and a drum switch to reverse rotation  L1 L2 120 VAC MANUAL STARTER 1 2 3 4 5 6 7 8 REV. DRUM SWITCH Fig. #29	A. Develop job circuit on chalkboard B. Review mounting of equipment C. Demonstrate job wiring of a drum switch used to reverse a split-phase motor D. Test job for proper operation in both directions	A. Discuss split phase motors 1. Circuitry 2. Operation 3. Reversing 4. Regulation 5. Dual-voltage type

46. Connect a capacitor-start motor to a manual starter, and a drum switch to reverse rotation	A. Display a capacitor-start motor and demonstrate its operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for a capacitor start motor E. Test job for proper operation in both directions	A. Discuss capacitor-start motors 1. Definition 2. Sizes 3. Applications 4. Construction a. Stator b. Rotor c. Centrifugal device d. Capacitor/s e. End shields
47. Connect a capacitor-start motor to an across-the-line magnetic starter operated from a stop-start station	A. Develop job circuit on chalkboard B. Review mounting of equipment C. Demonstrate job wiring for the circuit D. Test job for proper operation from the control station	A. Discuss capacitor-start motors 1. Circuitry 2. Operation 3. Reversing 4. Regulation 5. Dual-voltage types

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
48. Connect a repulsion-motor to a manual starter	A. Display a repulsion-motor and demonstrate its operation B. Develop job circuit on chalkboard C. Demonstrate job wiring for the circuit D. Test job for proper operation	A. Discuss repulsion motors 1. Definition 2. Three types 3. Applications 4. Maintenance problems 5. Reversing
49. Connect a repulsion-motor to an across-the-line magnetic starter operated from two start-stop stations	A. Display a repulsion-motor and demonstrate how it is reversed B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for the circuit E. Test the job for proper operation from both control stations	A. Discuss repulsion-motors 1. Principle of operation 2. Dual-voltage types 3. Construction a. End shields b. Single winding stator c. Wound armature d. Centrifugal assembly 1. Necklace and barrel 2. Brushes 3. Weights, rods and spring 4. Radial commutator

50. Connect a capacitor-start motor to an across-the-line magnetic starter operated by a float switch	A. Review capacitor-start motor operation B. Develop job circuit on chalkboard C. Review mounting of equipment D. Demonstrate job wiring for the circuit E. Test job for proper operation from the float switch	A. Discuss capacitors 1. Definition 2. Applications 3. Construction 4. Capacitor life 5. Types 6. Capacitors in multiple

Unit VI: Industrial Electronics

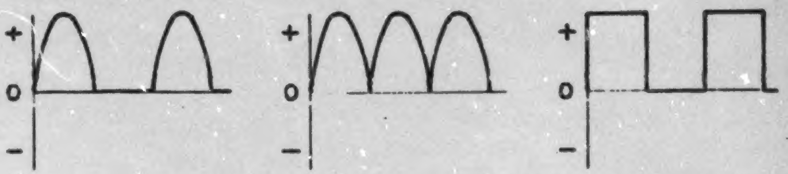
Level Three: Motors and Controls
Suggested Time: *100 Hours / 150 Periods*

Performance Objectives

Upon completion of this unit, the student will be able to:

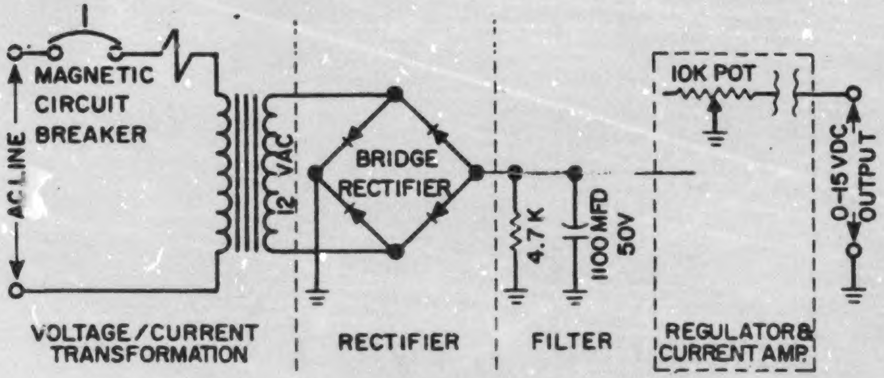
- Wire a D.C. power supply.
- Wire a solid—state bridge rectifier circuit.
- Wire a ripple output circuit from rectifier and filters.
- Wire a Go/No-Go transistor testor.
- Wire a triac and diac into a circuit.
- Wire a low voltage control circuit using a triac.
- Wire a SCR variable speed controller with motor reversing capabilities.
- Troubleshoot faulty wiring in solid-state control circuits.

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
1. Wire a D.C. power supply Note: These circuits may be constructed by using either separate components or trainers. The circuits in this unit follow the outline used by the Lab-Volt Company using trainer #A 2000. Additional information will be found in the manual which accompanies the trainer. Student manuals are also available	A. Illustrate on chalkboard and discuss forms of pulsating D.C. (See Fig. #2) B. Develop job circuit on chalkboard (See Fig. #1) C. Demonstrate 1. Wiring the job circuit 2. Measuring voltages at input and output sides of transforms 3. Measuring voltage at D.C. output 4. Varying potentiometer setting and noting effect on voltage output	A. Discuss D.C. power supplies 1. Purpose 2. Functions a. Transformation b. Rectification c. Filtering d. Regulation



Forms of Pulsating DC

Fig. #2

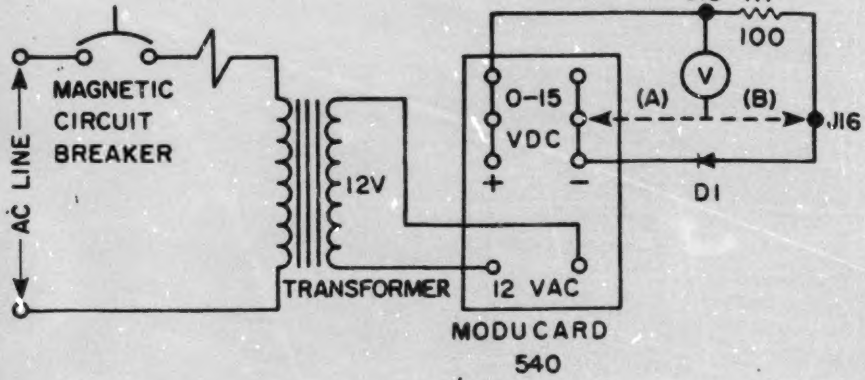

MAGNETIC
CIRCUIT
BREAKER
AC LINE
12 VAC
BRIDGE
RECTIFIER
4.7 K
1100 MFD
50V
10K POT
0-15 VDC
OUTPUT
VOLTAGE/CURRENT
TRANSFORMATION
RECTIFIER
FILTER
REGULATOR&
CURRENT AMP.

Partial Schematic Diagram of the DC Power Supply

Fig.#1

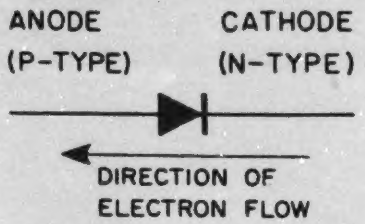
2. Wire a solid-state diode in a circuit

A. Illustrate on chalkboard and discuss
   1. Construction of solid-state diodes
   2. Diode configurations
   3. Forward and reverse bias
B. Develop job circuit on chalkboard (See Fig. #3)
C. Demonstrate:
   1. Wiring the job circuit
   2. Measuring voltage at input and output of transformer
   3. Measuring voltage at various points varying potentiometer
   4. Checking for forward and reverse bias


MAGNETIC
CIRCUIT
BREAKER
AC LINE
TRANSFORMER
12V
12 VAC
0-15
VDC
+
−
J15
R7
100
V
(A)
(B)
J16
D1
MODUCARD
540

The Experimental Circuit
Fig. #3

A. Discuss solid-state diodes
   1. Classification of materials as conductors, semi-conductors and insulators
   2. Materials: germanium and solicon
   3. Principle of operation
   4. Types
   5. Applications


ANODE
(P-TYPE)
CATHODE
(N-TYPE)
DIRECTION OF
ELECTRON FLOW

Symbol for a Diode
Fig. #4

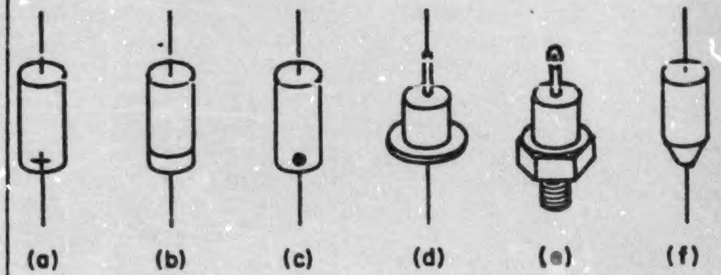
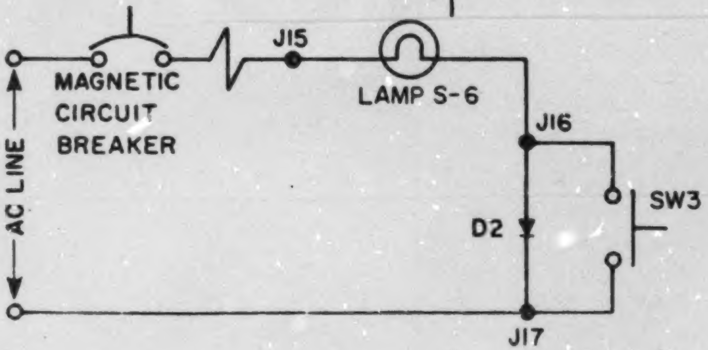


Fig. #5

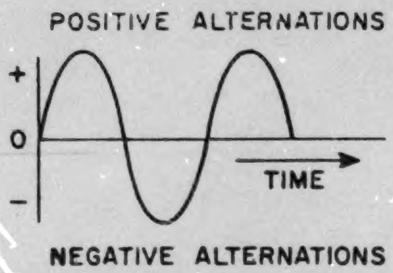
Various Types of Diode Configurations (a) Enclosed stack, (b) and (c) glass subminiature, (d) top-hat, (e) stud mounting, and, (f) epoxy type

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
3. Wire a Go/No-Go Diode Tester	A. Display several diodes and describe 1. Small, light and rugged 2. Not affected by aging, moisture and normal temperatures B. Develop the job circuit on the chalkboard (See Fig. #6) C. Demonstrate: 1. Job wiring for the circuit 2. Proper circuit operation a. Open diode opens lamp circuit b. Shorted diode causes lamp To light at full intensity regardless of whether SW3 is open or closed	A. Discuss how a diode can produce half wave pulsating D.C. (See Fig. #7) B. Discuss how parallel or series arrangement of rectifiers can provide higher voltate and current capabilities C. Discuss diode failures: Open circuit or short circuit usually caused by sudden temperature rise


MAGNETIC
CIRCUIT
BREAKER
J15
LAMP S-6
J16
SW3
D2
AC LINE
J17

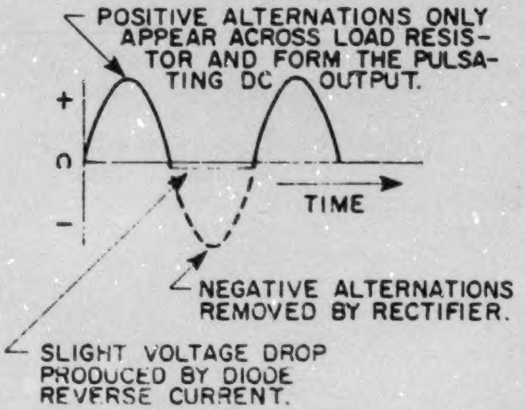
Co/No-Go Diode Tester

Fig. #6


POSITIVE ALTERNATIONS
+
0
−
TIME
NEGATIVE ALTERNATIONS

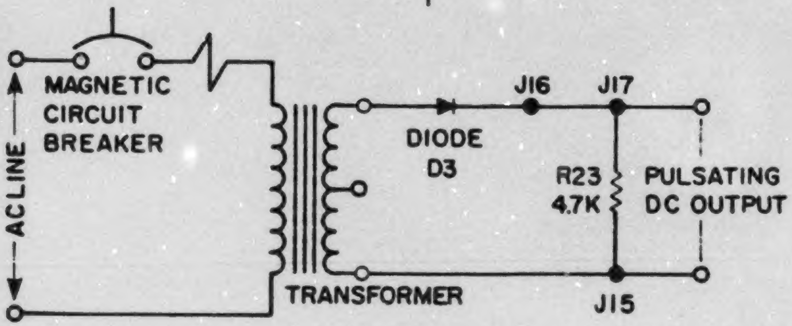
AC Waveform

Fig. #7


POSITIVE ALTERNATIONS ONLY APPEAR ACROSS LOAD RESISTOR AND FORM THE PULSATING DC OUTPUT.
+
0
−
TIME
NEGATIVE ALTERNATIONS REMOVED BY RECTIFIER.
SLIGHT VOLTAGE DROP PRODUCED BY DIODE REVERSE CURRENT.

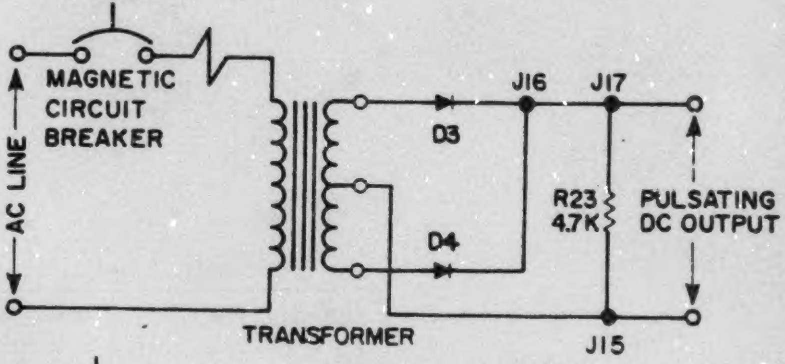
DC Waveform

4. Wire a solid-state rectifier circuit	A. On chalkboard, illustrate and discuss
	  1. Forms of half-wave rectification
	  2. Forms of full-wave rectification
	B. Develop job circuits on chalkboard (See Fig. #8 and Fig. #9)
	C. Demonstrate:
	  1. Wiring the job circuits
	  2. Measuring and comparing voltages obtained from half-wave and full-wave rectification
		A. Discuss rectifier circuits
		  1. Half-wave
		    a. Components
		    b. Circuitry
		    c. Applications
		    d. Disadvantages
		B. Full-wave
		  a. Components
		  b. Circuitry
		  c. Applications
		  d. Advantages


MAGNETIC
CIRCUIT
BREAKER
AC LINE
TRANSFORMER
DIODE
D3
J16
J17
R23
4.7K
PULSATING
DC OUTPUT
J15

Half-Wave Rectifier Circuit

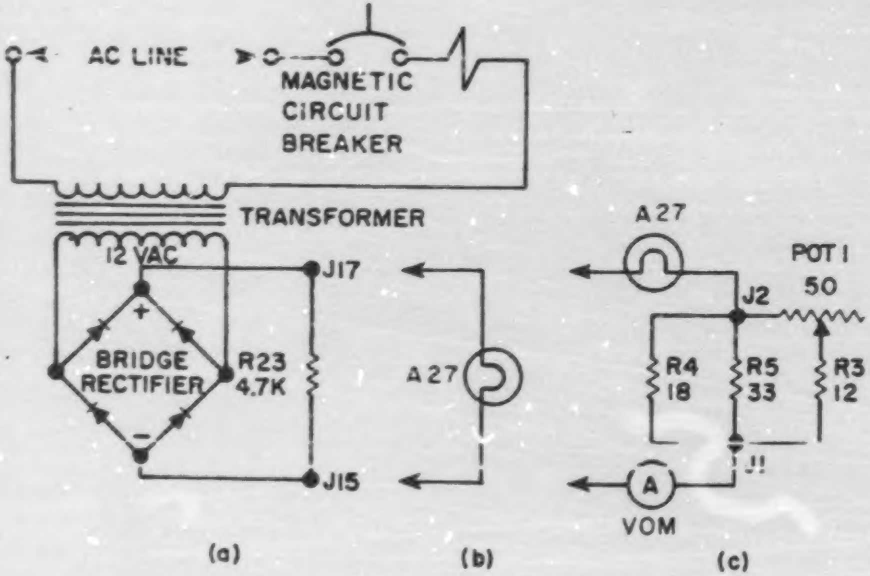
Fig. #8


MAGNETIC
CIRCUIT
BREAKER
AC LINE
TRANSFORMER
D3
D4
J16
J17
R23
4.7K
PULSATING
DC OUTPUT
J15

Full-Wave Rectifier Circuit

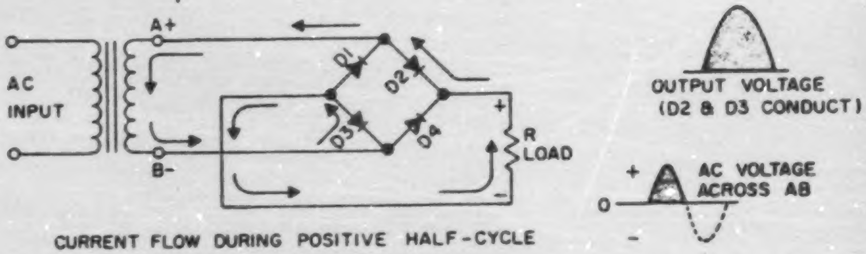
Fig. #9

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
5. Wire a solid-state bridge rectifier curcuit	A. On chalkboard, illustrate and discuss: 1. Bridge rectifier circuit 2. Current flow in positive and negative halves of A.C. cycle B. Develop the job circuit on chalkboard (See fig. #10) C. Demonstrate: 1. Wiring the job circuit 2. Measuring output voltages of circuits a, b, and c	A. Discuss the bridge rectifier 1. Components 2. Circuitry 3. Advantages 4. Applications


AC LINE
MAGNETIC CIRCUIT BREAKER
TRANSFORMER
12 VAC
+
BRIDGE RECTIFIER
-
R23 4.7K
J17
J15
A 27
A 27
POT I 50
J2
R4 18
R5 33
R3 12
J1
A
VOM
(a)
(b)
(c)

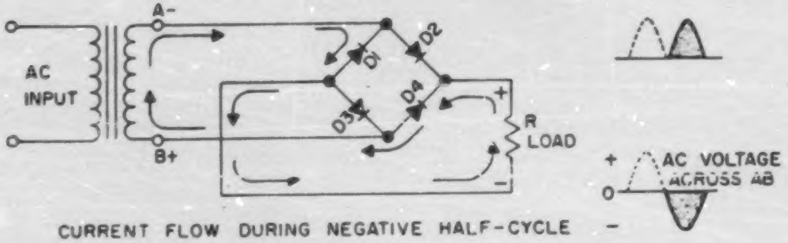
Experimental Bridge Rectifier Circuit

Fig. #10


AC INPUT
A+
B-
D1
D2
D3
D4
+
-
R LOAD
OUTPUT VOLTAGE (D2 & D3 CONDUCT)
+
0
-
AC VOLTAGE ACROSS AB

CURRENT FLOW DURING POSITIVE HALF-CYCLE
(ARROWS SHOW DIRECTION)

Fig. #11


AC INPUT
A-
B+
D1
D2
D3
D4
+
-
R LOAD
+
0
-
AC VOLTAGE ACROSS AB

CURRENT FLOW DURING NEGATIVE HALF-CYCLE

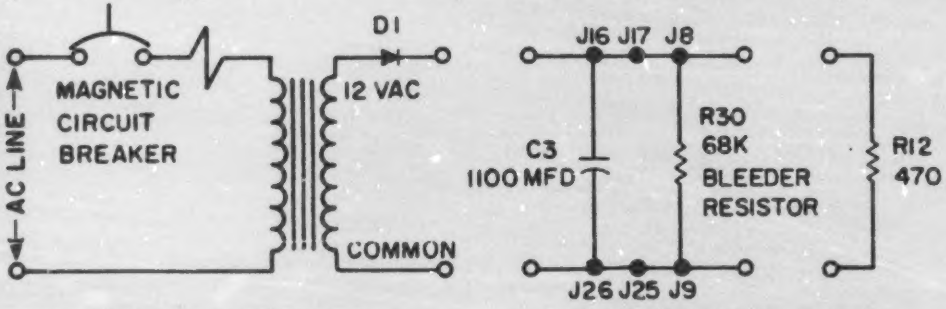
Fig. #12

6. Wire a power supply filter circuit

A. Develop
   1. Half-wave rectification with capacitance filtering circuit on chalkboard (See Fig. #13)
   2. Full-wave rectification with RC filtering on chalkboard (See Fig. #14)

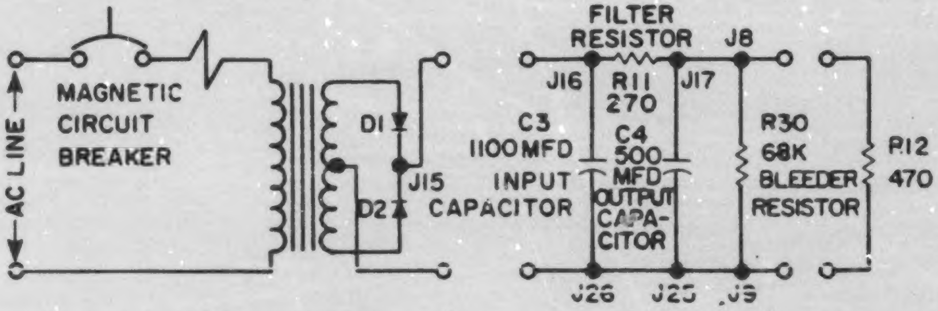
B. Demonstrate
   1. Job wiring circuits A-B and C-D
   2. Measuring and comparing voltage

A. Discuss filtering
   1. Purpose
   2. Action of capacitors
   3. Purpose of Pi network
   4. Type of filter circuits


D1
AC LINE
MAGNETIC CIRCUIT BREAKER
12 VAC
COMMON
J16 J17 J8
C3 1100 MFD
R30 68K BLEEDER RESISTOR
R12 470
J26 J25 J9

(a) HALF-WAVE RECTIFIER (b) CAPACITANCE FILTER

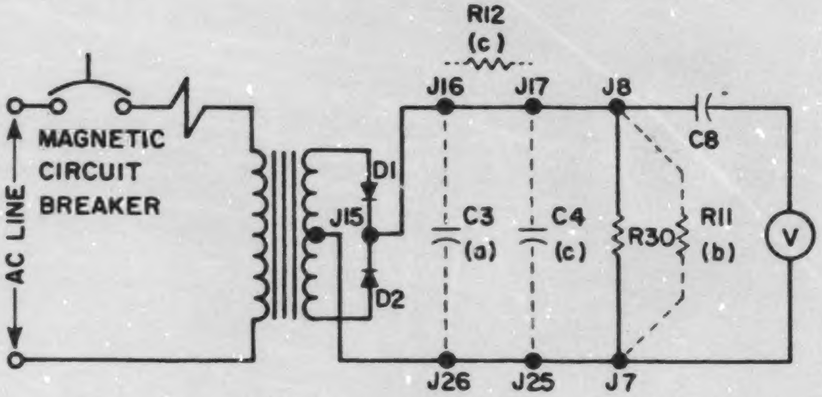
Fig. #13


AC LINE
MAGNETIC CIRCUIT BREAKER
D1
D2
J15
FILTER RESISTOR
J16
R11 270
J17
J8
C3 1100 MFD INPUT CAPACITOR
C4 500 MFD OUTPUT CAPACITOR
R30 68K BLEEDER RESISTOR
R12 470
J26 J25 J9

(c) FULL-WAVE RECTIFIER (d) RC FILTER

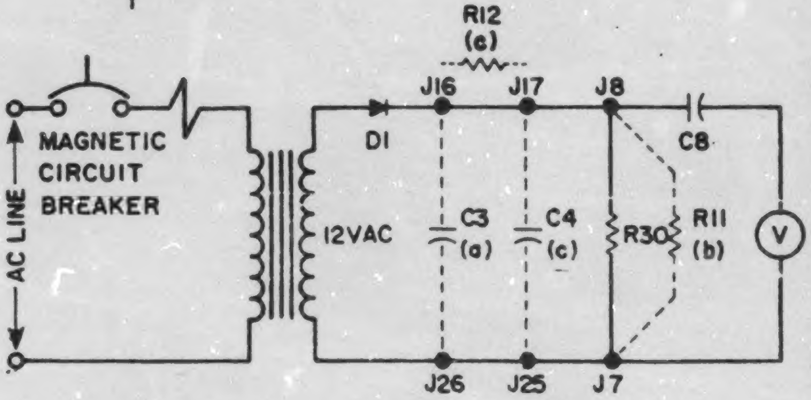
Fig. #14

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
7. Wire a ripple output circuit from rectifiers and filters	A. On blackboard, illustrate and discuss: 1. Half-wave rectification curves without filtering and with filtering 2. Full-wave rectification curves without filtering and with filtering B. Develop job circuits on chalkboard (See Fig. #15 and #16) C. Demonstrate: 1. Job wiring for circuits 2. Comparing ripple of two circuits by comparing voltages	A. Discuss ripple output 1. Meaning 2. Effect 3. Ripple on half-wave 4. Ripple on full-wave 5. Use of oscilloscope to measure ripple


R12
(c)
J16
J17
J8
C8
MAGNETIC
CIRCUIT
BREAKER
AC LINE
D1
J15
D2
C3
(a)
C4
(c)
R30
R11
(b)
V
J26
J25
J7

Full-Wave Experimental Circuit

Fig. #15


R12
(c)
J16
J17
J8
D1
C8
MAGNETIC
CIRCUIT
BREAKER
AC LINE
12VAC
C3
(a)
C4
(c)
R30
R11
(b)
V
J26
J25
J7

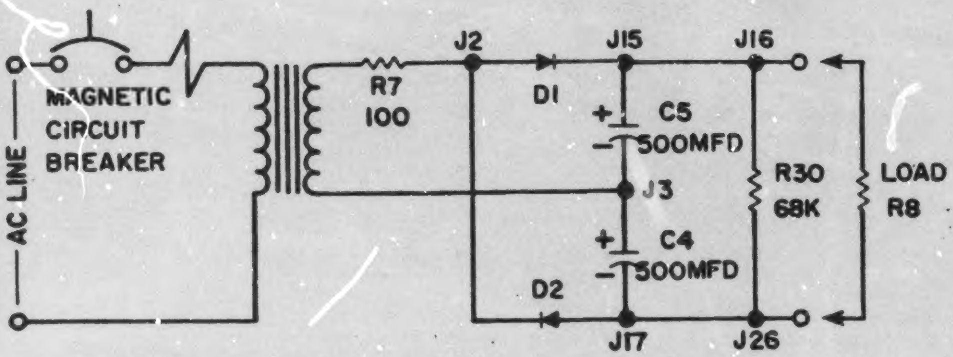
Half-Wave Experimental Circuit

Fig. #16

8. Wire a voltage multiplier/doubler circuit

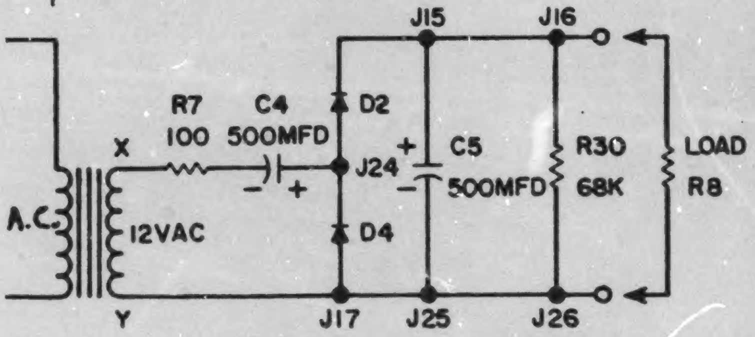
A. Using Fig. #17
  1. Discuss principles of voltage doubling
  2. Trace circuitry
B. Develop job circuits on chalkboard (See Figs. #17 and #18)
C. Demonstrate
  1. Wiring job circuit (See Figs. #17 and #18)
  2. Measuring and comparing output voltages and ripple of two circuits

A. Discuss voltage multipliers
  1. Meaning
  2. Advantage
  3. Functions of voltage multiplier
    a. Voltage modification
    b. Rectification


AC LINE
MAGNETIC
CIRCUIT
BREAKER
R7
100
J2
D1
J15
J16
C5
500MFD
J3
R30
68K
LOAD
R8
C4
500MFD
D2
J17
J26

Experimental Full-Wave Voltage Doubler

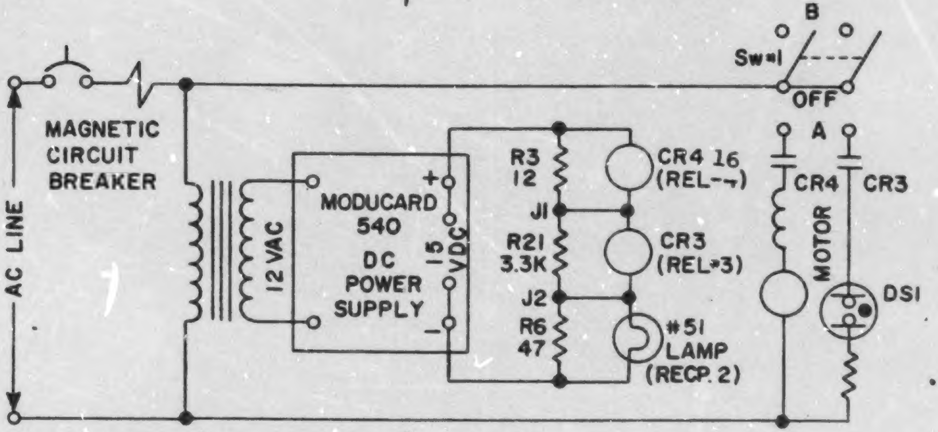
Fig. #17


J15
J16
R7
100
C4
500MFD
D2
X
C5
500MFD
R30
68K
LOAD
R8
J24
A.C.
12VAC
D4
Y
J17
J25
J26

Experimental Cascade Voltage Doubler

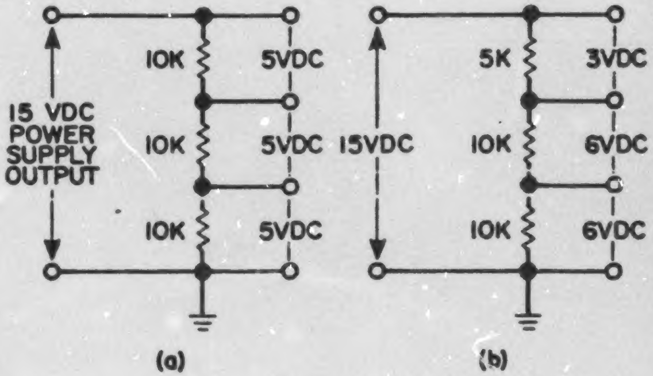
Fig. #18

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
9. Wire a voltage-divider circuit	A. Using the voltage divider circuits (Fig. #20), discuss how the final overall design of a circuit is accomplished through consideration of load resistances and dividers B. Develop job circuit on chalkboard (See Fig. #19) C. Demonstrate: 1. Job wiring for the circuit 2. Measuring voltage at each divider resistor 3. Noting effect on motor operation with varying loads connected across dividers	A. Discuss voltage-dividing purpose 1. Purpose 2. Review series circuits 3. Use circuits below to discuss action of voltage in series circuits


B
Sw#1
OFF
A
MAGNETIC CIRCUIT BREAKER
AC LINE
12 VAC
MODUCARD 540
DC POWER SUPPLY
+
-
15 VDC
R3 12
J1
R21 3.3K
J2
R6 47
CR4 16 (REL-4)
CR3 (REL#3)
#51 LAMP (RECP. 2)
CR4
CR3
MOTOR
DS1

Experimental Voltage Divider Circuit

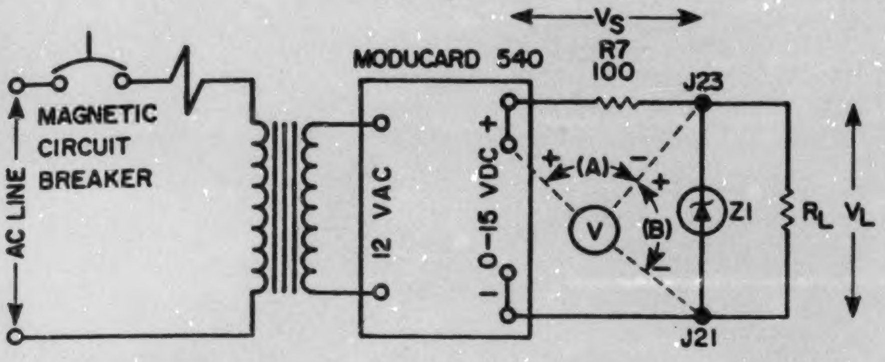
Fig. #19


15 VDC POWER SUPPLY OUTPUT
10K
10K
10K
5VDC
5VDC
5VDC
(a)
15VDC
5K
10K
10K
3VDC
6VDC
6VDC
(b)

Voltage Dividers

Fig. #20

10. Wire a zener diode circuit


VS
MODUCARD 540
R7
100
J23
J21
MAGNETIC
CIRCUIT
BREAKER
AC LINE
12 VAC
0–15 VDC
+
−
(A)
(B)
V
Z1
RL
VL

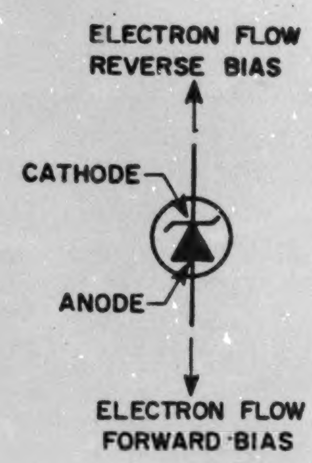
Experimental Zener Diode Regulator

Fig. #21

A. Develop the job circuit on the chalkboard (See Fig. #21)

B. Demonstrate:
   1. Job wiring for the circuit
   2. Checking voltages in order to show how the zener maintains a constant voltage despite large changes in load current

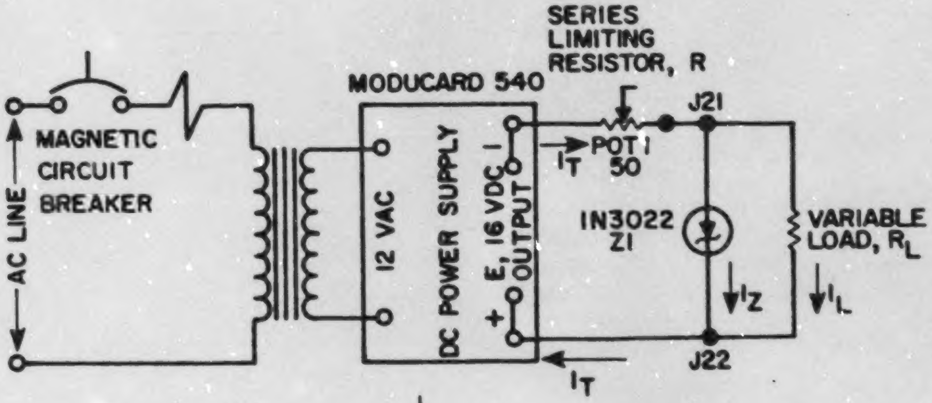
A. Discuss the zener diode
   1. Review of diodes
   2. Function of zener diodes
   3. Construction of zener
   4. Characteristics


ELECTRON FLOW
REVERSE BIAS
CATHODE
ANODE
ELECTRON FLOW
FORWARD BIAS

Schematic Symbol

Fig. #22

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
11. Wire a zener regulator circuit	A. Using a block diagram, review the four stages of a power supply system B. Develop job circuit on chalkboard (See Fig. #23) C. Demonstrate: 1. Job wiring for the circuit 2. Measuring voltages to show how the zener regulates output voltage	A. Discuss the zener regulator 1. Review the zener construction and principle of operation 2. Review the four functions of a Power supply 3. Discuss why regulators are necessary 4. Discuss three types of regulators 5. Describe several advantages of zeners


SERIES LIMITING RESISTOR, R
MODUCARD 540
MAGNETIC CIRCUIT BREAKER
AC LINE
12 VAC
DC POWER SUPPLY
E, 16 VDC OUTPUT
+
POT 1 50
I_T
J21
IN3022 Z1
VARIABLE LOAD, R_L
I_Z
I_L
J22
I_T

Zener Diode Shunt Regulator Circuit

Fig. #23

12. Wire a common emitter circuit using a transistor

A. Place Fig. #25 on chalkboard and describe construction and operation of transistors
B. Develop job circuit on chalkboard (See Fig. #24)
C. Demonstrate:
   1. Job wiring for circuit
   2. Measure voltages to show action of a transistor in a circuit

A. Discuss transistors
   1. Definition
   2. Junction transistor
      a. Construction
      b. Types
      c. Symbols
      d. Principle of operation

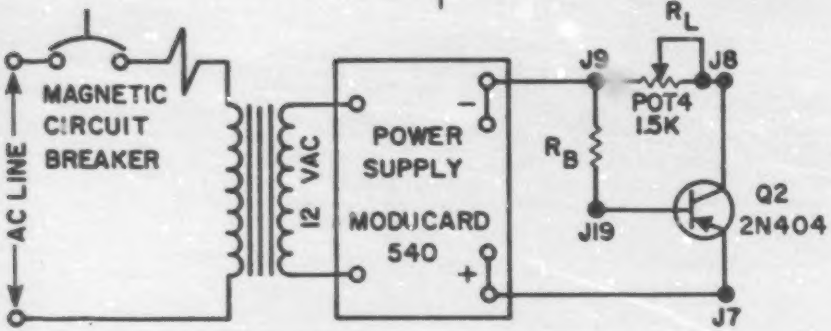
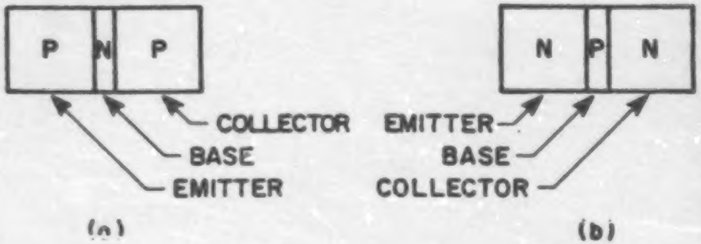

AC LINE
MAGNETIC CIRCUIT BREAKER
12 VAC
POWER SUPPLY
MODUCARD 540
−
+
J9
R_L
J8
POT4 1.5K
R_B
J19
Q2 2N404
J7

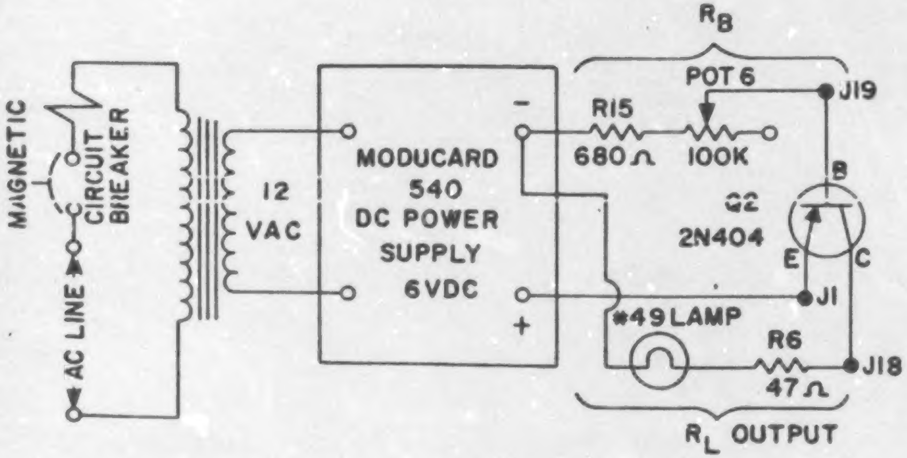
Fig. #24


P
N
P
COLLECTOR
BASE
EMITTER
(a)
N
P
N
EMITTER
BASE
COLLECTOR
(b)

(a) PNP Transistor, (b) NPN Transistor

Fig. #25

Tasks	TEACHING CONTENT	
	Development of Skills	Development of Related Information
13. Wire a Go/No-Go transistor tester	A. Discuss how a simple tester can be constructed to test whether a transistor is good or bad B. Develop job circuit on chalkboard (See Fig. #26) C. Demonstrate: 1. Job wiring for the circuit 2. How the circuit is used to test a transistor	A. Discuss transistors 1. Applications 2. Advantages 3. Types of configurations 4. Direction of current flow using circuits below



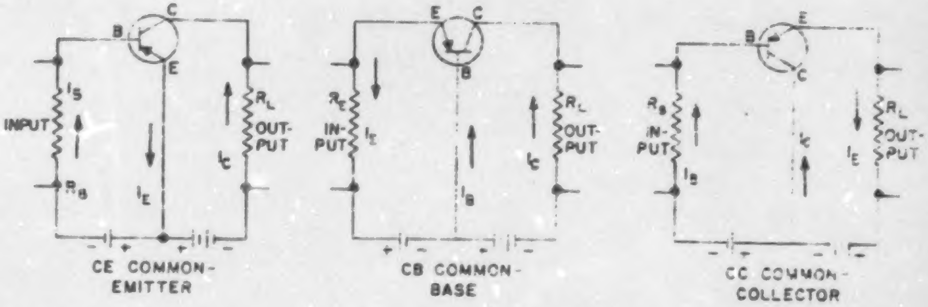
MAGNETIC CIRCUIT BREAKER
AC LINE
12 VAC
MODUCARD 540 DC POWER SUPPLY 6VDC
-
+
R_B
POT 6
R15
680Ω
100K
J19
B
Q2
2N404
E
C
J1
#49 LAMP
R6
47Ω
J18
R_L OUTPUT

Experimental Circuit and Transistor Tester

Fig. #26

Fig. #27

Transistor Circuit Configuration



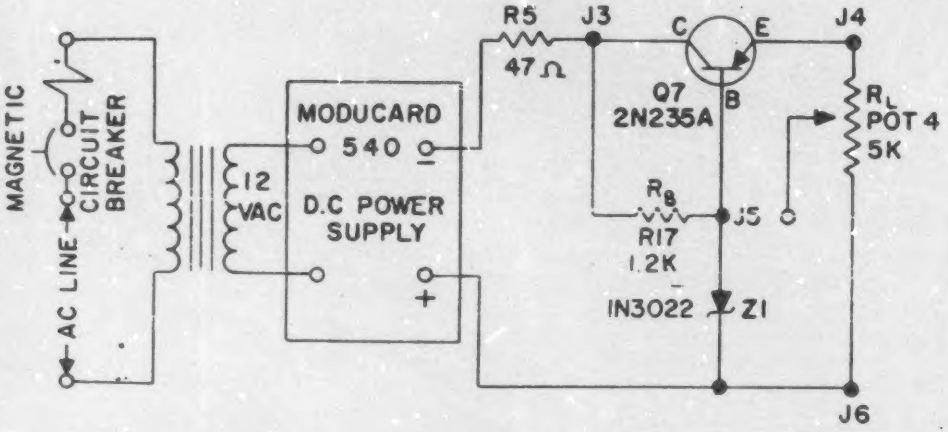
B
C
E
I_S
INPUT
R_B
I_E
R_L
OUTPUT
I_C
CE COMMON-EMITTER
E
C
B
R_E
INPUT
I_E
I_B
R_L
OUTPUT
I_C
CB COMMON-BASE
B
E
C
R_B
INPUT
I_B
I_C
I_E
R_L
OUTPUT
CC COMMON-COLLECTOR

14. Wire a zener transistor series regulator circuit

A. Develop the job circuit on the chalkboard. (See Fig. #28)

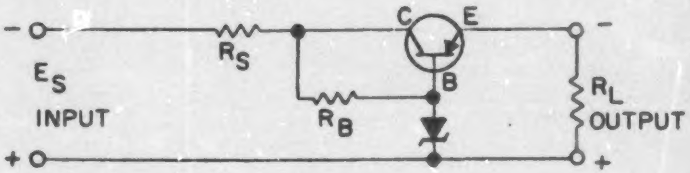
B. Demonstrate
   1. Job wiring for the circuit
   2. Checking output voltages as potentiometer resistance is varied to show good regulation obtained with this circuit

A. Discuss the zener transistor series regulator
   1. Zener limitations
   2. Need for voltage regulation
   3. Function of the zener in the circuit
   4. Functions of the transistor


MAGNETIC
CIRCUIT BREAKER
AC LINE
12 VAC
MODUCARD 540
D.C POWER SUPPLY
−
+
R5
47Ω
J3
C
E
J4
Q7
2N235A
B
R_L
POT 4
5K
R_B
R17
1.2K
J5
IN3022
Z1
J6

Experimental Zener-Transistor Series Regulator Circuit

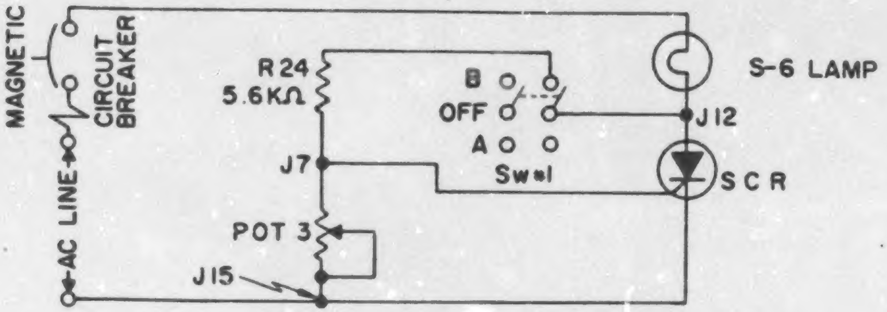
Fig. #28


−
E_S
INPUT
+
R_S
C
E
B
R_B
R_L
OUTPUT
−
+

Basic Zener-Transistor Series Regulator Circuit

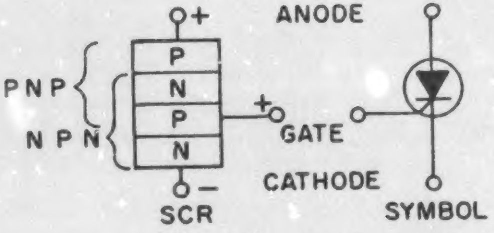
Fig. #29

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
15. Wire a silicon controlled rectifier in a circuit	A. Place illustrations at bottom right on chalkboard and use to discuss symbol, physical arrangement and current flow in an SCR B. Develop job circuits on chalkboard (See Figs. #30 and #31) C. Demonstrate 1. Job wiring for circuits 2. Switching action of an SCR through triggering of its gate	A. Discuss the silicon controlled rectifier 1. Definition 2. Advantages 3. Characteristics 4. Principle of operation


MAGNETIC
CIRCUIT BREAKER
AC LINE
R24
5.6KΩ
B
OFF
A
Sw#1
J7
POT 3
J15
J12
S-6 LAMP
SCR

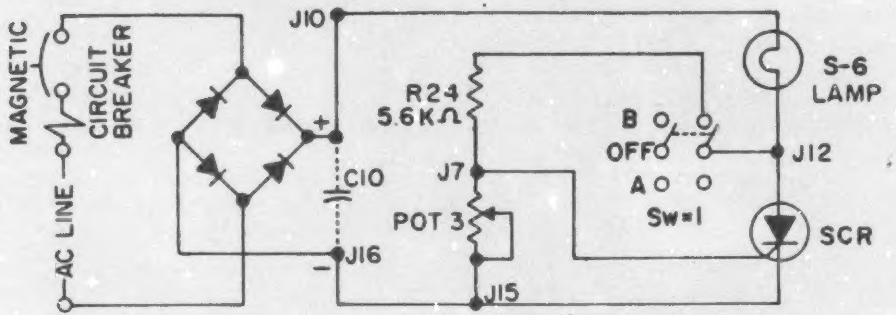
AC Control With AC Gate

Fig. #30


+
ANODE
P
N
P
N
PNP
NPN
+
GATE
−
CATHODE
SCR
SYMBOL

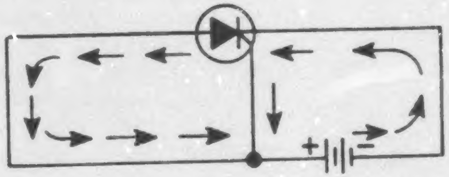
Physical Arrangement of an SCR and its Symbol

Fig. #32


MAGNETIC
CIRCUIT BREAKER
AC LINE
J10
+
C10
−
J16
R24
5.6KΩ
J7
POT 3
J15
B
OFF
A
Sw#1
J12
S-6 LAMP
SCR

DC Control with DC Gate

Fig. #31



Current Flow in an SCR

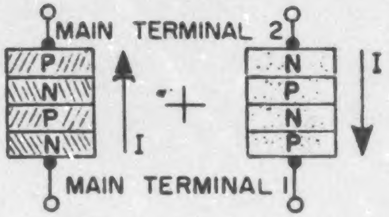
Fig. #33

BEST COPY

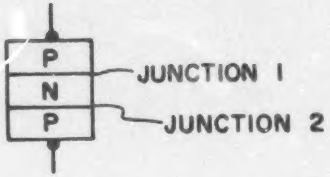
16. Wire a triac and diac in a circuit

A. Place illustration at bottom right on chalkboard and discuss triacs and diacs
B. Develop job circuits on chalkboard (See Figs. #34 and #35)
C. Demonstrate:
  1. Job wiring for the circuits
  2. Testing circuit to show how the diac triggers the triac into conduction

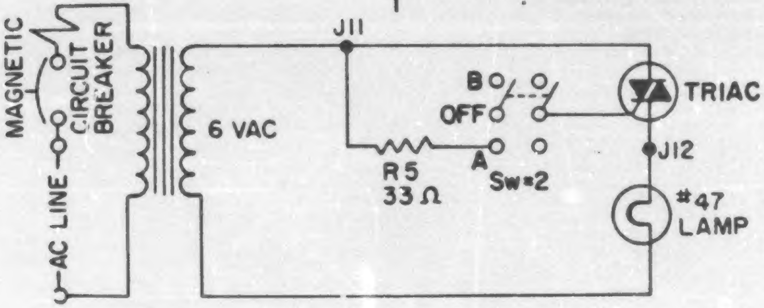
A. Discuss the triac and diac
  1. Definition
  2. Construction
  3. Symbol
  4. Applications


MAIN TERMINAL 2
P
N
P
N
I
+
N
P
N
P
I
MAIN TERMINAL 1

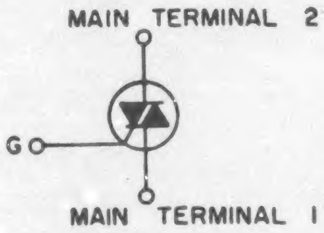
Junction Diagram of a Triac


P
N
P
JUNCTION 1
JUNCTION 2

Diac Junction Diagram

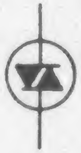

MAGNETIC
CIRCUIT BREAKER
AC LINE
6 VAC
J11
B
OFF
A
Sw#2
R5
33 Ω
TRIAC
J12
#47
LAMP

Triac Test Circuit Fig. #34


MAIN TERMINAL 2
G
MAIN TERMINAL 1

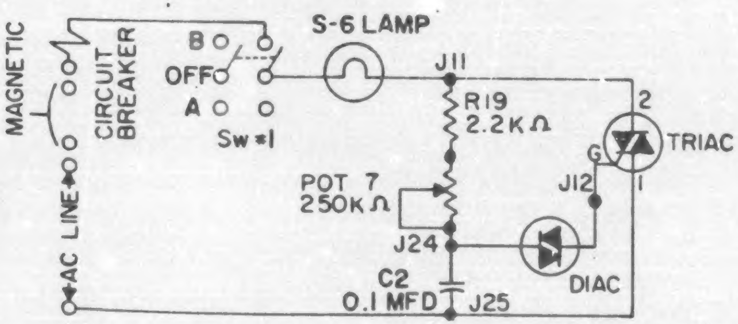
Triac Symbol

Fig. #36



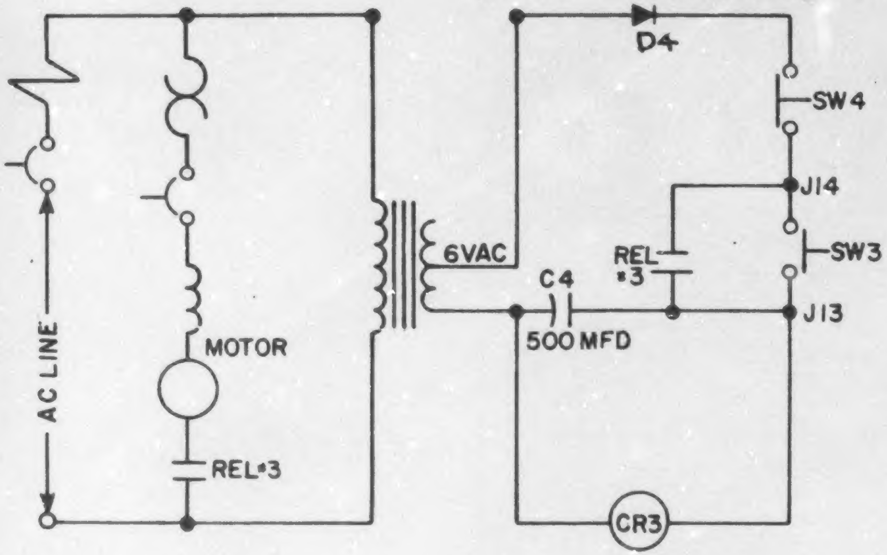
Diac Symbol

Fig. #37


MAGNETIC
CIRCUIT BREAKER
AC LINE
B
OFF
A
Sw#1
S-6 LAMP
J11
R19
2.2K Ω
POT 7
250K Ω
J24
C2
0.1 MFD
J25
J12
DIAC
G
2
1
TRIAC

Basic Triac/Diac Control Circuit Fig. #35

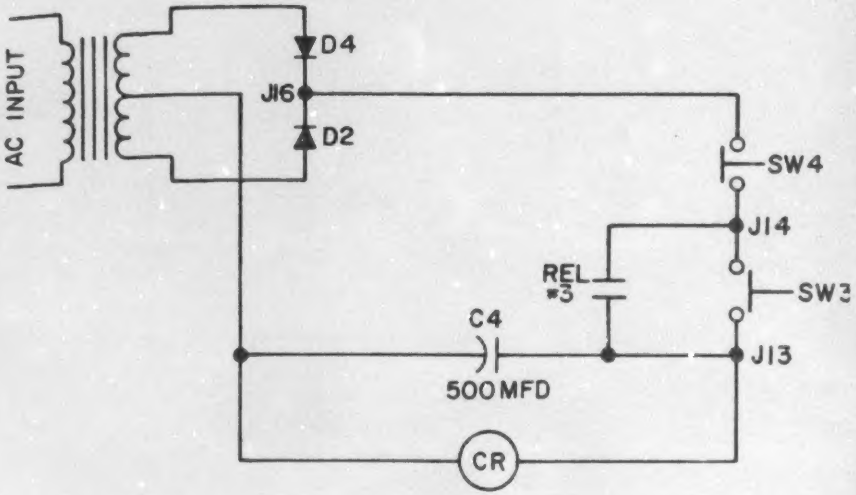
	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
17. Wire a low-voltage control circuit, using half-wave and full-wave rectification	A. Review motor control 1. Power circuit components 2. Control circuit components B. Develop the job circuits on the chalkboard (See Figs. #38 and #39) C. Demonstrate 1. Wiring the job circuits 2. Checking operation of half-wave circuit and proving that capacitor filtering is necessary 3. Checking operation of full-wave circuit and proving filtering is not necessary	A. Discuss low-voltage control 1. Advantages: Safety and economy 2. Equipment required 3. Circuitry


AC LINE
MOTOR
REL*3
6VAC
D4
SW4
J14
REL *3
SW3
C4
500 MFD
J13
CR3

POWER CIRCUIT

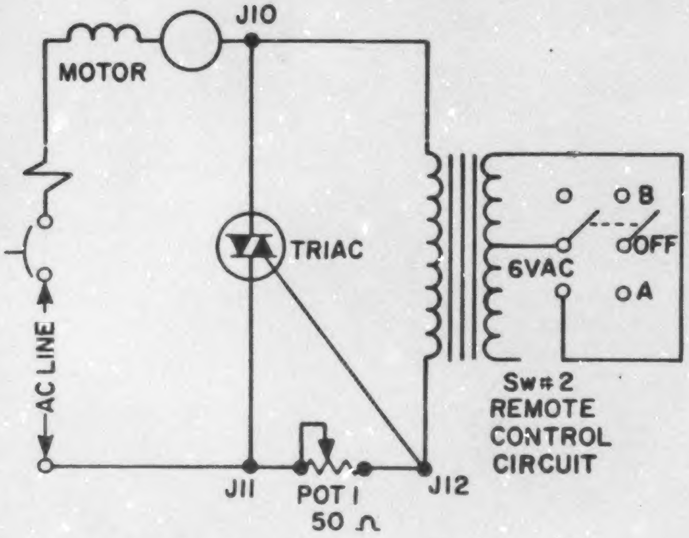
LOW-VOLTAGE CONTROL CIRCUIT

Low-Voltage Control Using a Half-Wave Rectifier and DC Relay
Fig. #38


AC INPUT
D4
J16
D2
SW4
J14
REL *3
SW3
C4
500 MFD
J13
CR

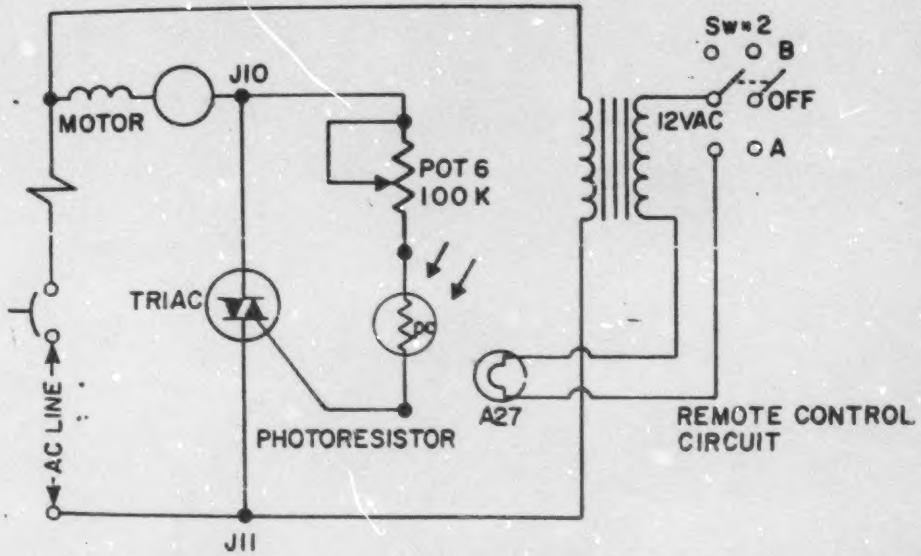
Low-Voltage Control Using a Full-Wave Rectifier and DC Relay
Fig. #39

18. Wire low-voltage control circuits using a triac	A. Develop the job circuits on the chalkboard (See Figs. #40 and #41) B. Demonstrate 1. Job wiring of the circuits 2. Testing to show operation of motor through triac when remote control circuit is closed 3. Testing to show operation of motor through triac when light is applied to photoresistor	A. Discuss the triac 1. Review its construction and function 2. Low-voltage control applications 3. Advantages over relays and contacters B. Discuss photoresistors 1. Principle of operation 2. Applications


J10
MOTOR
TRIAC
AC LINE
J11
POT I
50 Ω
J12
6VAC
B
OFF
A
Sw#2
REMOTE
CONTROL
CIRCUIT

Triac Triggered by Transformer Current

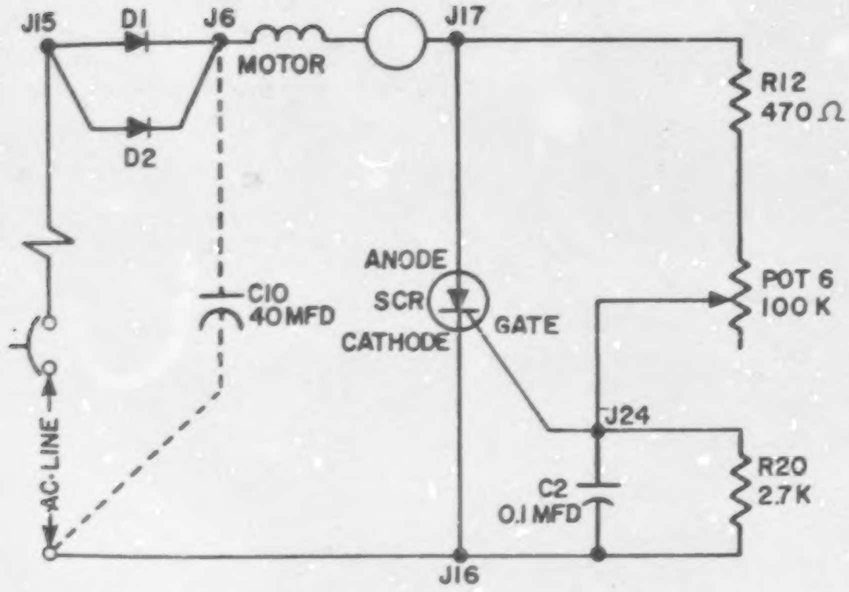
Fig. #40

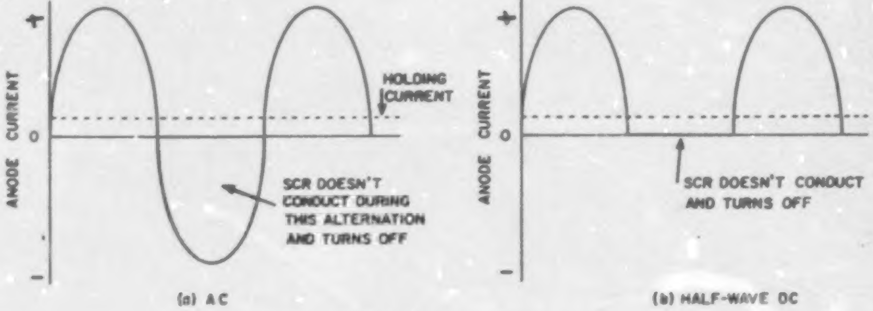

J10
MOTOR
POT 6
100 K
TRIAC
AC LINE
PHOTORESISTOR
A27
J11
Sw#2
B
OFF
12VAC
A
REMOTE CONTROL
CIRCUIT

Triac Triggered by Light

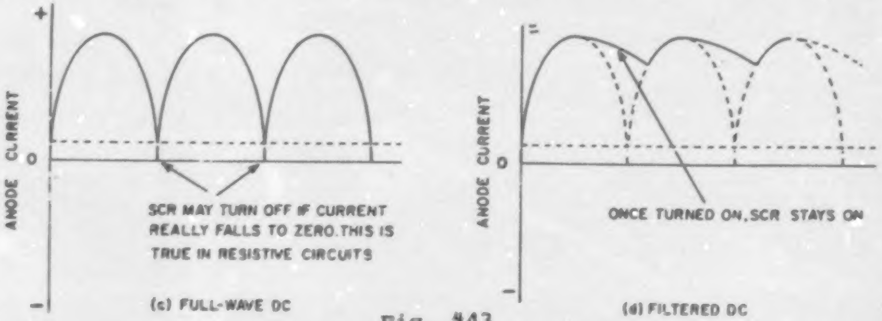
Fig. #41

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
19. Wire a motor control circuit using half-wave rectification and SCR	A. Using illustrations at bottom right, discuss action of an SCR, using A.C. and half-wave, full-wave and filtered D.C. B. Develop job circuit on chalkboard. (See Figs. #42 and #43) C. Demonstrate: 1. Job wiring for circuit 2. Testing circuit to show that speed of the motor is controlled by varying potentiometer resistance, which controls gate current of the SCR	A. Discuss the silicon controlled rectifier (SCR) 1. Review its construction and function 2. Ease of conduction 3. Conduction characteristics


J15
D1
J6
MOTOR
J17
D2
R12
470 Ω
ANODE
SCR
CATHODE
GATE
C10
40 MFD
POT 6
100 K
AC LINE
J24
C2
0.1 MFD
R20
2.7K
J16



Experimental SCR Motor Control Circuit



SCR Anode Current for Various AC and DC Conditions

Fig. #42

Fig. #43

20. Wire a motor control circuit using full-wave rectification and SCR

A. Review differences between inductive and resistive loads

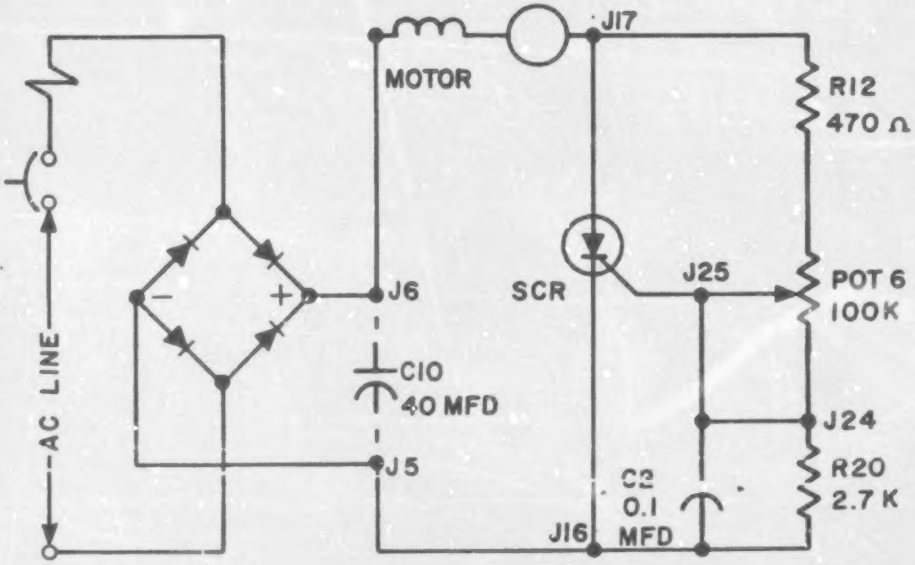
B. Develop job circuit on chalkboard. (See Fig. #44)

C. Demonstrate
   1. Job wiring for circuit
   2. Operation of motor thorough SCR with partial filtering which maintains SCR
   3. Replacing motor load with a resistive load to show SCR cannot maintain

A. Review the bridge rectifier circuit

B. Review how an SCR operates

C. Discuss how an inductive load acting as a type of filter can maintain an SCR circuit while a purely resistive load cannot


MOTOR
J17
R12
470 Ω
AC LINE
−
+
J6
SCR
J25
POT 6
100K
C10
40 MFD
J24
J5
R20
2.7 K
C2
0.1
MFD
J16

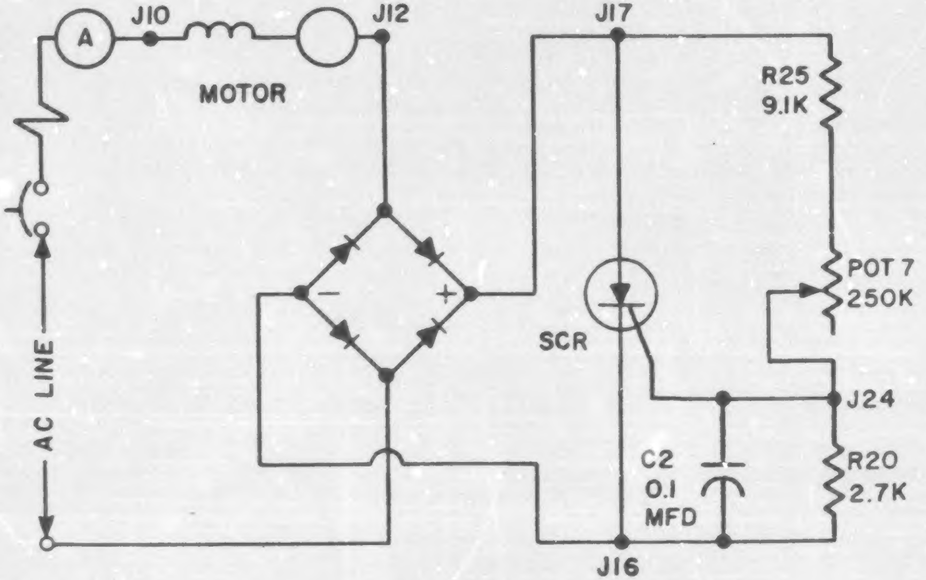
Experimental SCR Control Circuit

Fig. #44

366

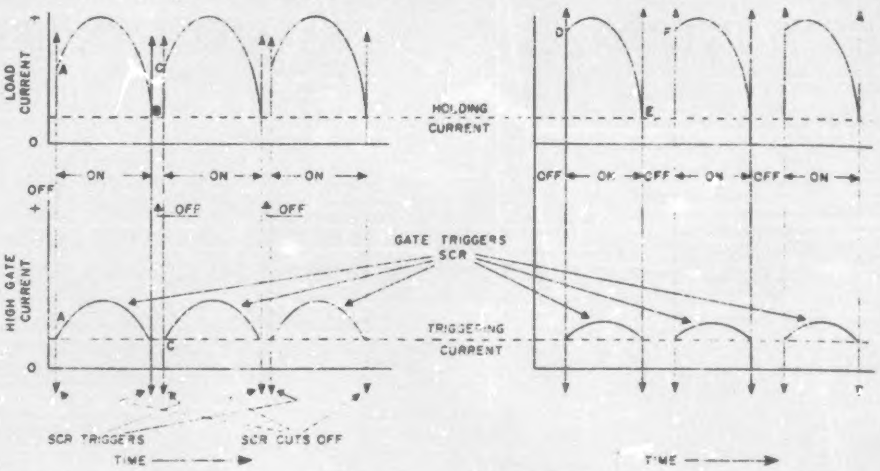
367

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
21. Control and AC motor with SCR using D.C.	A. Develop job circuit on chalkboard. (See Fig. #45) B. Demonstrate: 1. Job wiring for circuit 2. Testing circuit to show how speed control of motor is accomplished through gate circuit of the SCR the current of which is varied by the potentiometer	A. Discuss SCR triggering (See Fig. #46) 1. Effect of gate current on load. In "A," gate current exceeds triggering current level 70% of the time. In "C," gate current exceeds level only 30% of the time, causing SCR to conduct only 70% of the time. With A.C. load current, SCR would be on only half of time in each previous example



Experimental SCR Control Circuit

Fig. #45



(a) SCR LOAD CURRENT AND GATE CURRENT (HIGH, ON 70%)

(c) SCR LOAD CURRENT AND GATE CURRENT (LOW, ON 30%)

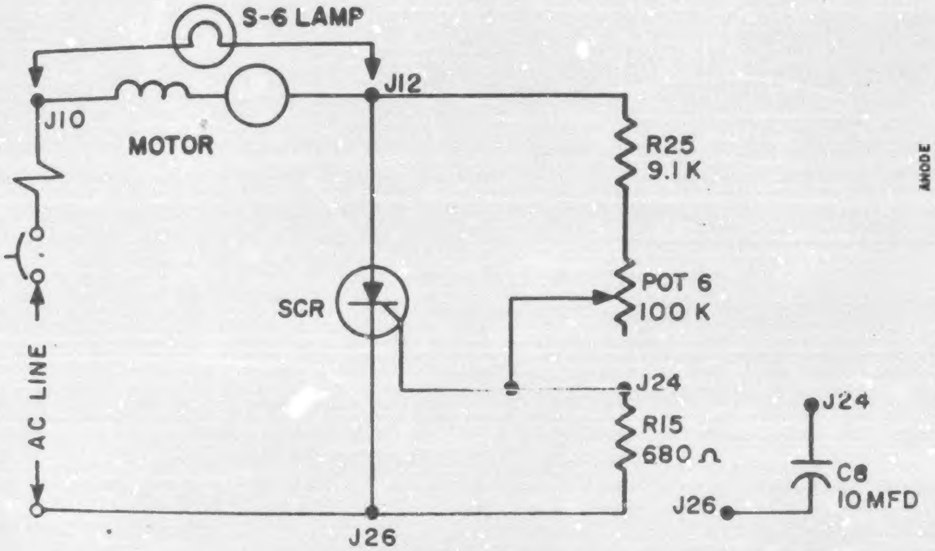
Fig. #46

22. Control an A.C. motor with an SCR using A.C.

A. Develop job circuit on chalkboard. (See Fig. #47)

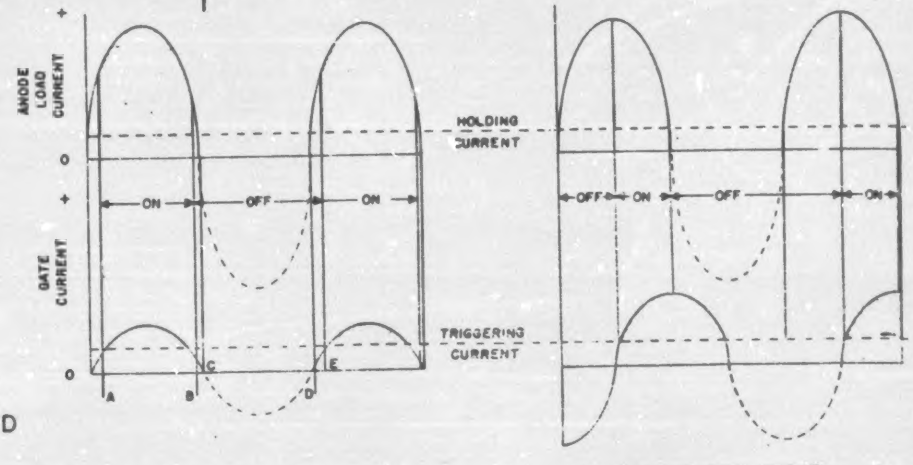
B. Demonstrate
   1. Job wiring for circuit
   2. Testing circuit with resistance in gate circuit and noting effects of motor
   3. Testing circuit replacing resistance in gate circuit with a capacitor and noting effects

A. Discuss phase shift effect on an SCR (See Fig. #48)
   1. In a half-wave resistive circuit, SCR conducts for slightly less than half of the time
   2. In a half-wave capacitive gate circuit there is a phase shift of the gate


S-6 LAMP
J12
J10
MOTOR
R25
9.1K
SCR
POT 6
100 K
J24
R15
680 Ω
AC LINE
J26
J24
C8
10 MFD
J26

Experimental SCR Control Circuit

Fig. #47

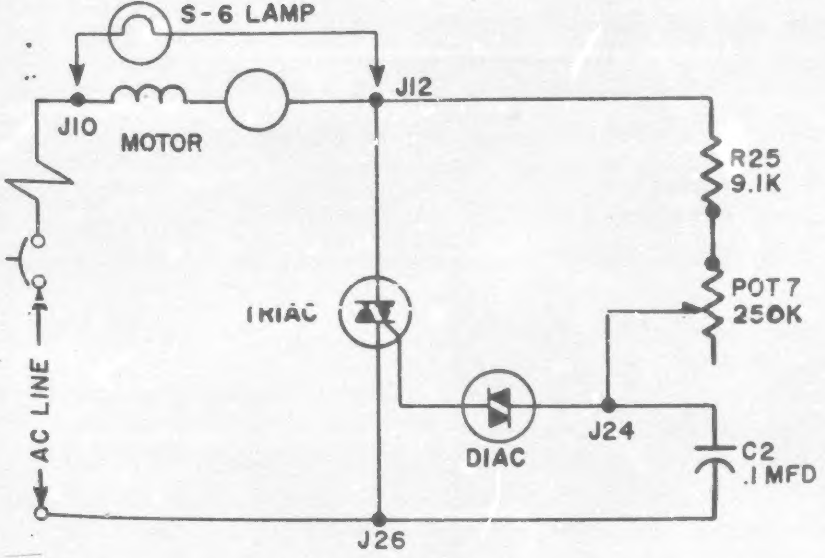


(a) RESISTIVE GATE CIRCUIT

(b) CAPACITIVE GATE CIRCUIT

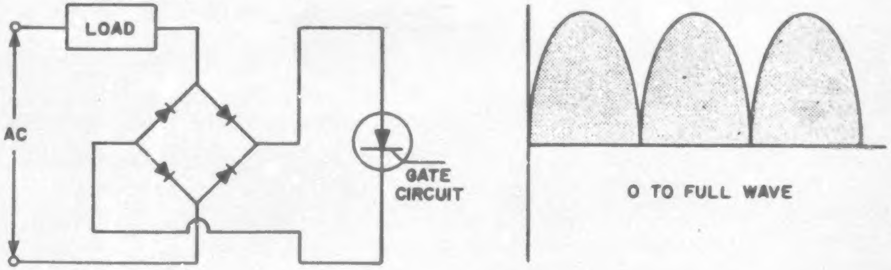
Fig. #48

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
23. Wire a basic diac/triac motor control system	A. Compare type of control available with a bridge rectifier circuit and a full-wave triac circuit (See Fig. # 50) B. Develop job circuit on chalkboard. (See Fig. #49) C. Demonstrate 1. Job wiring for circuit 2. Testing circuit to show control of an inductive load and a resistive load by a triac trigger triggered by a diac	A. Discuss the triac 1. Function: semi-conductor switch 2. Advantage of improved control for AC power 3. Advantages: simple, efficient, reliable 4. Applications: motors, lamps, heaters


S-6 LAMP
J12
J10
MOTOR
R25
9.1K
POT 7
250K
TRIAC
DIAC
J24
C2
.1 MFD
AC LINE
J26

Experimental Diac/Triac Control Circuit

Fig. #49


LOAD
AC
GATE CIRCUIT
0 TO FULL WAVE

CONTROLLED FULL-WAVE (AC OR DC) BRIDGE - SCR CIRCUIT

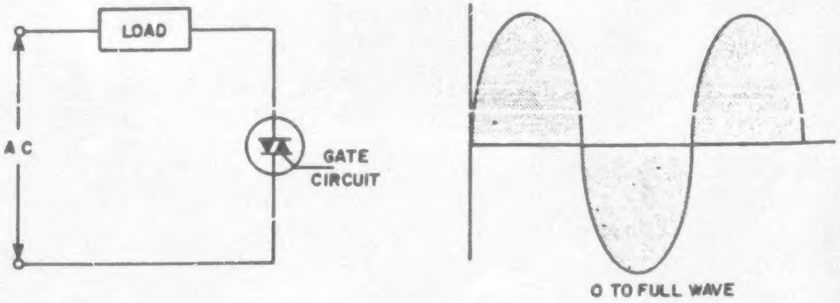
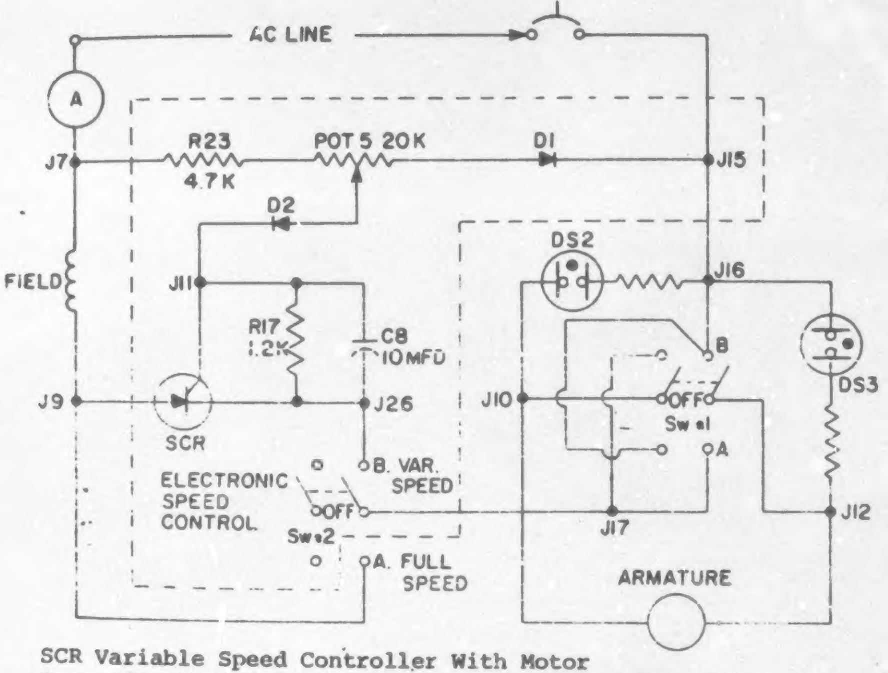

LOAD
AC
GATE CIRCUIT
0 TO FULL WAVE

Fig. #50 CONTROLLED FULL-WAVE TRIAC CIRCUIT

24. Wire an SCR variable speed controller with motor reversing capabilities

A. Develop job circuit on chalkboard. (See Fig. #51)

B. Demonstrate
   1. Job wiring for the circuit
   2. Motor reversing through operation of switch #1
   3. Full speed operation by setting switch #2 to position A. This bypasses the electronic control
   4. Speed control operation by setting switch #2 to position B. This places armature in series with the SCR

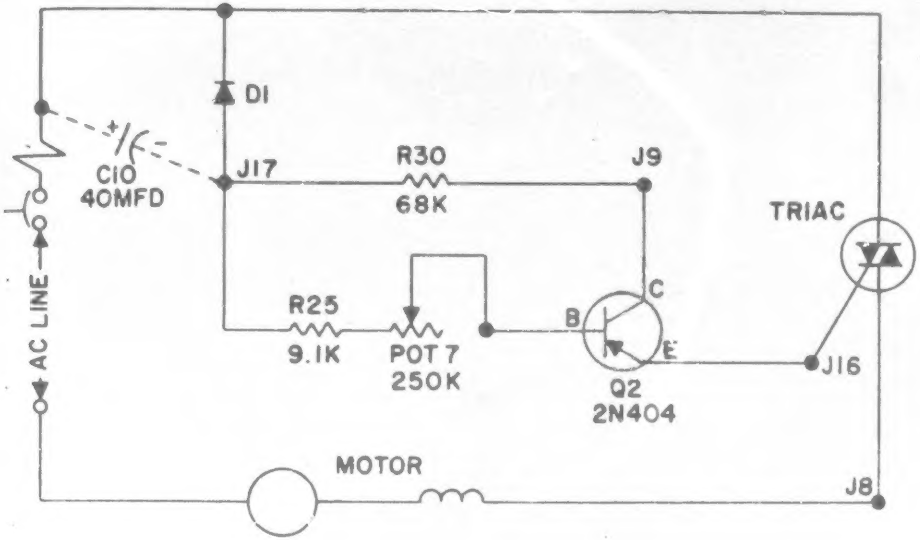

AC LINE
A
J7
R23
4.7K
POT 5 20K
D1
J15
D2
FIELD
J11
R17
1.2K
C8
10MFD
DS2
J16
DS3
J9
SCR
J26
J10
B
OFF
Sw #1
A
J12
ELECTRONIC SPEED CONTROL
B. VAR. SPEED
OFF
Sw #2
A. FULL SPEED
J17
ARMATURE

SCR Variable Speed Controller With Motor Reversing Capabilities

Fig. #51

A. Discuss electronic control of motors
   1. Disadvantages of resistors, selenium rectifiers, thyratrons
      a. Bulky
      b. Expensive
      c. Poor regulation
   2. Advantages of electronic control
      a. Compact
      b. Inexpensive
      c. Excellent regulation
   3. Applications: conveyors, packing, equipment, printing presses, copy machines

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
25. Wire a motor control circuit using a transistor as a static switch	A. Discuss use of transistors in motor control circuits 1. Cut off state-open 2. Saturated state-closed B. Develop job circuit on chalkboard. (See Fig. #52) C. Demonstrate 1. Job wiring for circuit 2. Operation of the motor through the triac when the transistor changes from cutoff state to saturated state by lowering potentiometer resistance	A. Discuss changes in industrial control due to use of semi-conductors 1. Components replaced by semi-conductors Thyatrons Contactors Starters Fuses Transformers Thermostats Limit switches Timers Rheostats Vacuum tubes 2. Semi-conductor applications a. Food processing-controlling liquid level b. Textiles-detection of breaks in thread and flaws in fabrics c. Post offices-sorting systems d. Bakeries-control of conveyors e. Tire making-control of curing temperatures f. Punch presses-monitoring material feed



Experimental Static Switching Circuit

Fig. #52

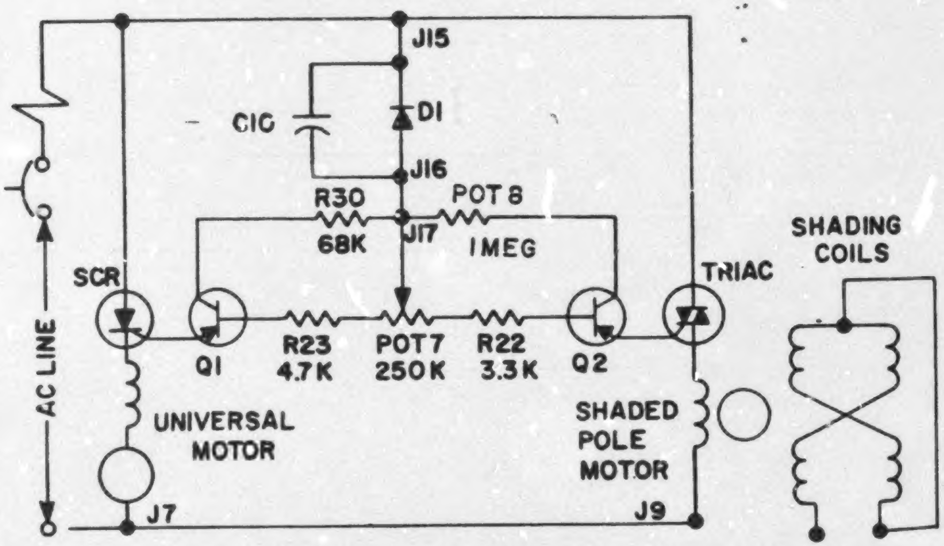
26. Interlock two motors using solid-state control

A. Discuss interlocking and give examples in industry, if necessary

B. Develop job circuit on blackboard (See Fig. #53)

C. Demonstrate
   1. Job wiring for circuit
   2. How operation of the potentiometer permits either motor to run but not at the same time

A. Discuss motor interlocking
   1. Definition-taping two circuits together so that one controls the other
   2. Purpose-to ensure that machine operations are performed in the correct sequence at the proper time
   3. Advantages of semi-conductors over electromechanical components
      a. Economy
      b. Simplicity
      c. Reliability


J15
CIC
DI
J16
R30
68K
POT 8
J17
IMEG
SHADING
COILS
SCR
TRIAC
AC LINE
Q1
R23
4.7K
POT7
250K
R22
3.3K
Q2
UNIVERSAL
MOTOR
SHADED
POLE
MOTOR
J7
J9

Experimental Solid-State Interlocking Motor Control Circuit

Fig. #53

BEST COPY

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
27. Wire a motor control circuit for dynamic braking and speed control using semi-conductors	A. Discuss the three major branches in the circuit (See Fig. #54) 1. Speed control branch 2. Braking current branch 3. Timing branch B. Develop the job circuit on the chalkboard (See Fig.#54) C. Demonstrate 1. Job wiring of the circuit 2. Operation of motor when switch #2 is on B. This triggers triac. Speed is controlled by potentiometer 3. Braking of motor when switch #2 is on A. The triac is removed and D.C. is applied to motor field through D1 and the relay	A. Discuss dynamic braking 1. Purpose-bring motors to a. Dead stop from full speed 2. Principle of operation-momentary passing a large direct current through the field with the resulting induced eddy current in the motor bringing the rotor to a halt 3. Applications for shaded pole motor dynamic braking circuits a. Machine tool control b. Vending machines c. Appliances control

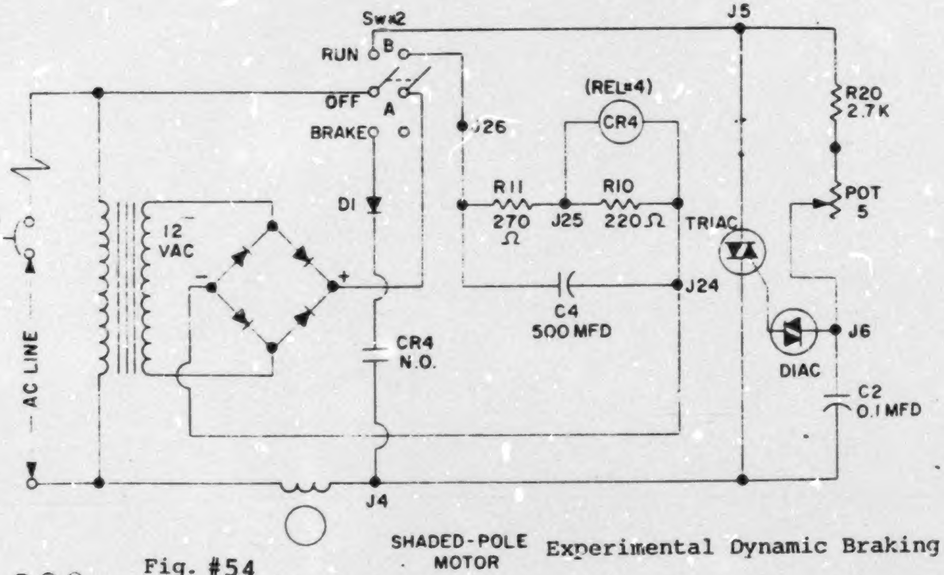

SW#2
RUN
B
OFF
A
BRAKE
J26
(REL#4)
CR4
J5
R20
2.7K
POT
5
R11
270 Ω
J25
R10
220Ω
TRIAC
DI
12
VAC
-
+
C4
500 MFD
J24
J6
DIAC
C2
0.1 MFD
CR4
N.O.
AC LINE
J4
SHADED-POLE
MOTOR

Fig. #54 Experimental Dynamic Braking Circuit

28. Wire two motors for sequential starting using a transistor for smoother control

A. Describe sequence starting. Note that motor operated by CR2 cannot be started unless motor operated by CR1 is in operation (See Fig. #56)

B. Develop job circuit on chalkboard (See Fig. #55)

C. Demonstrate
   1. Job wiring for circuit
   2. Operation of circuit with switch #2 on position A. Note time delay between start of shaded pole motor and universal motor

A. Discuss sequential starting
   1. Definition
   2. Applications: Where a machine must have auxiliary equipment operating before it can be used safely
   3. Types: mechanical, electro-mechanical, static (solid-state)
   4. Advantages of solid-state types
      a. Automatic timing between events
      b. Greater timing range and accuracy

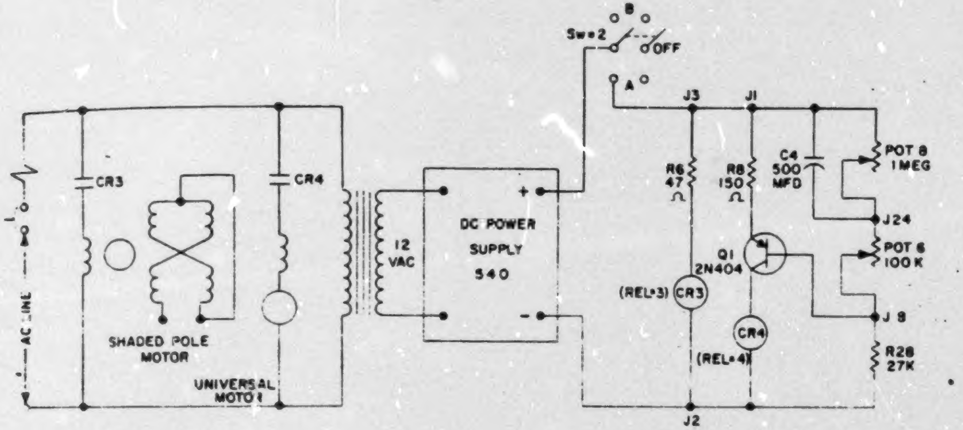
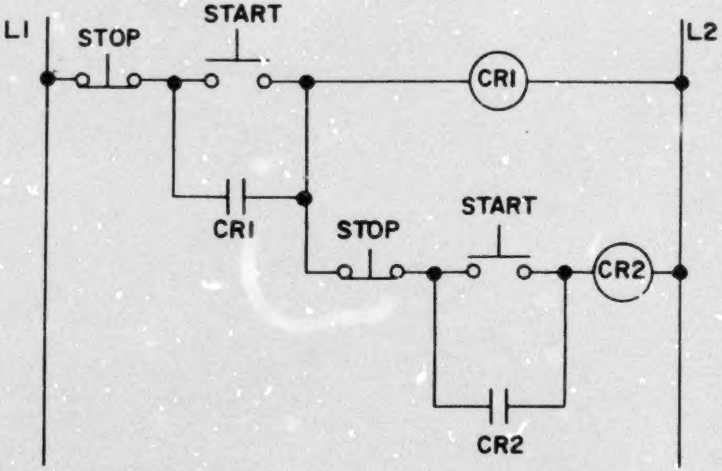

Sw#2
B
OFF
A
J3
J1
AC LINE
CR3
CR4
SHADED POLE MOTOR
UNIVERSAL MOTOR
12 VAC
DC POWER SUPPLY 540
+
-
R6 47 Ω
R8 150 Ω
C4 500 MFD
POT 8 1MEG
J24
Q1 2N404
POT 6 100K
(REL#3) CR3
CR4
(REL#4)
J8
R28 27K
J2

Fig. #55

Experimental Sequential Starting Circuit


L1
L2
STOP
START
CR1
CR1
STOP
START
CR2
CR2

A Starting System Wired for Sequence Control

Fig. #56

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
29. Wire a thermistor in a temperature bridge circuit	A. Discuss the bridge circuit used for the job (three fixed resistors and one potentiometer) 1. When potentiometer resistance is equal to thermistor, the bridge is balance and the meter reads zero 2. If heat is applied to thermistor, its resistance decreases, bridge balance is upset and meter indicates current flow B. Develop job circuit on chalkboard (See Fig. #57) C. Demonstrate: 1. Job wiring of circuit 2. Operation of circuit by setting switch #1 to A and balancing bridge by varying potentiometer; observe meter when heat or cold is applied to thermistor	A. Discuss thermistors 1. Definition: temperature sensitive resistors 2. Characteristics: good sensitivity and fast response to small temperature changes 3. Construction: metal oxides 4. Shapes 5. Application: temperature control

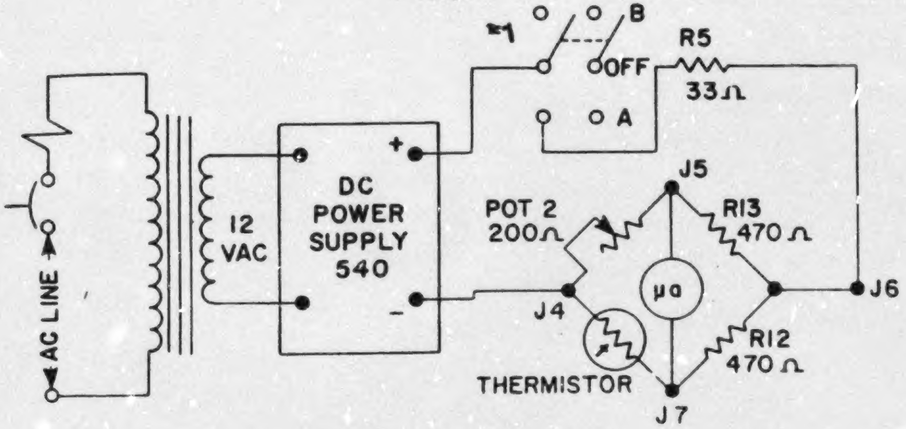


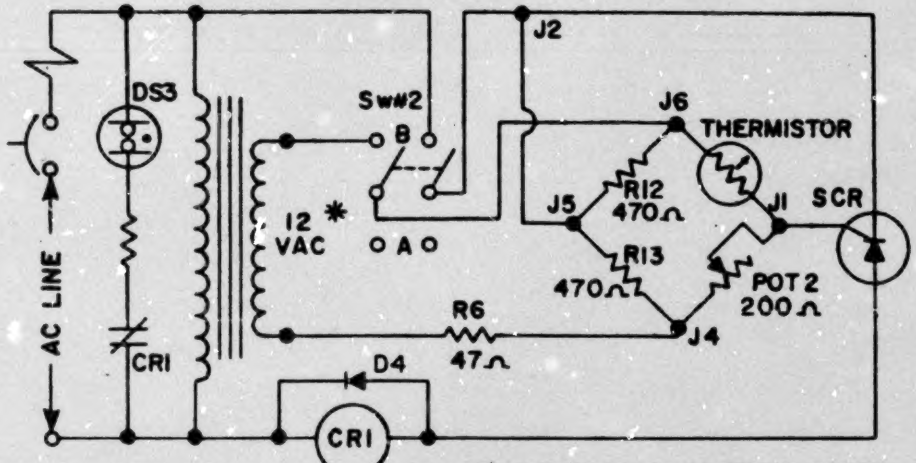
Fig. #57 Schematic Diagram of Temperature Bridge

30. Wire a thermal control circuit using an SCR and thermistor

A. Develop job circuit on chalkboard (See Fig. #58)

B. Demonstrate
  1. Job wiring for circuit
  2. Checking the circuit for proper operation
    a. Balancing the bridge by varying the potentiometer
    b. Triggering of the SCR upon temperature change in themistor this energized relay CR1 and opens load circuit

A. Discuss thermal control circuits
  1. Need for precise temperatures in industrial processes: food industry, cement and lime kilns, ceremic kilns
  2. Review thermistors
  3. Describe how a bridge circuit containing a thermistor can be used to trigger an SCR into conduction


J2
Sw#2
B
A
J6
THERMISTOR
DS3
12 VAC
*
R12 470Ω
J5
J1
SCR
R13 470Ω
POT 2 200Ω
R6 47Ω
J4
D4
47Ω
CR1
AC LINE
CR1

* SECONDARY MUST BE IN PHASE WITH THE PRIMARY

Fig. #58 Experimental Thermal Control Circuit

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
31. Wire a light activated motor-control circuit.	A. Display photoelectric devices and describe their functions B. Develop job circuit on chalkboard (See Fig. #59) C. Demonstrate 1. Job wiring of circuit 2. Operation of the photoresistor in combination with the diac and triac to start and stop the motor	A. Discuss photoelectric devices 1. Definition: Devices which respond to light energy 2. Types a. Photoconductive-change resistance b. Photoemissive-emit electrons c. Photovoltaic-generate 3. Applications: counting, measuring, warning, controlling 4. Materials: selenium, cadmium, sulfide, lead sulfide, lead selenide

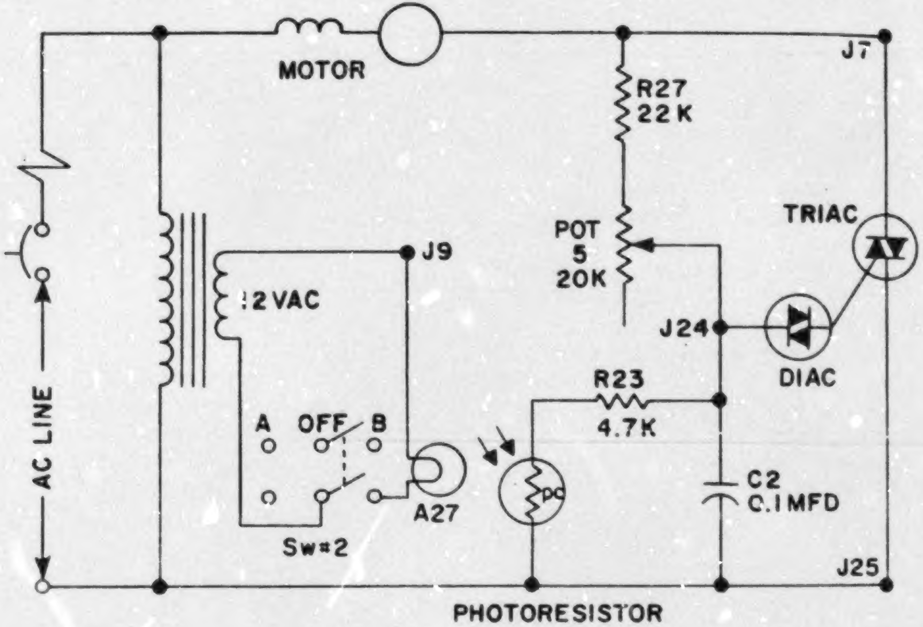

MOTOR
J7
R27
22K
TRIAC
POT
5
20K
J9
:2VAC
J24
DIAC
R23
4.7K
A
OFF
B
A27
PC
C2
C.1MFD
Sw*2
J25
AC LINE
PHOTORESISTOR

Fig. #59 Light-Activated Motor Controller

32. Wire a light-activated visual alarm circuit

A. Discuss the operation of the two-stage direct coupled transistor amplifier using an NPN and a PNP transistor

B. Develop job circuit on chalkboard (See Fig. #60)

C. Demonstrate
   1. Job wiring for circuit
   2. Operation of circuit by varying resistance in the biasing network or changing value of feedback capacitor to change rate at which alarm blinks on and off

A. Discuss light activated visual alarms
   1. Purpose: visual alarm, monitoring
   2. Applications: used in the boiler room of a large industrial plant for monitoring the flame or pilot flame of gas or oil-fired burners
   3. Operation: an indicator lamp blinks on and off when flame from boiler illuminates a photoelectric device

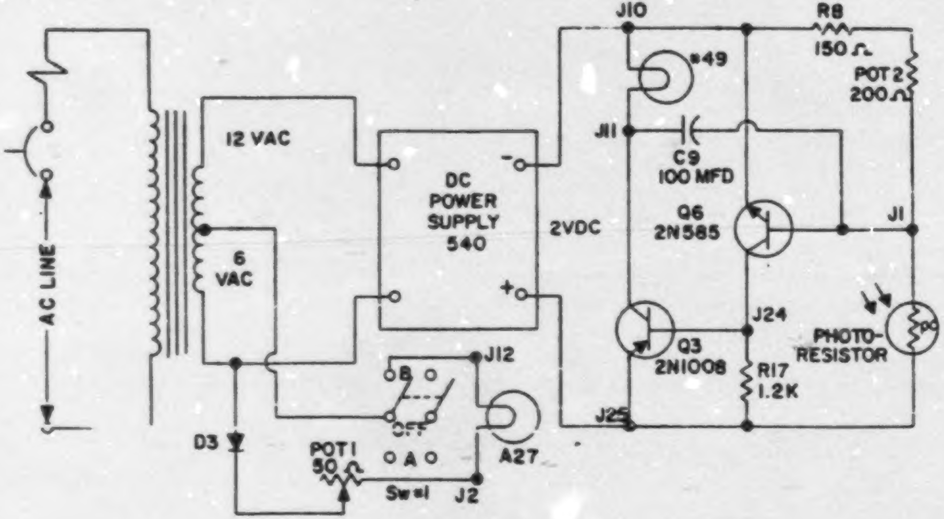

J10
R8
150Ω
#49
POT2
200Ω
J11
C9
100 MFD
12 VAC
DC
POWER
SUPPLY
540
2VDC
Q6
2N585
J1
6
VAC
AC LINE
J24
PHOTO-
RESISTOR
Q3
2N1008
R17
1.2K
J12
B
OFF
A
A27
J25
D3
POT1
50Ω
Sw#1
J2

Fig. #60 Light-Activated Visual Alarm

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
33. Wire a delayed action light-sensitive control circuit	A. Discuss how in this job a photoelectric device is combined with a transistor control circuit and an RC timing circuit to provide a simple means of light-sensing control B. Develop job circuit on chalkboard (See Fig. #61) C. Demonstrate 1. Job wiring for circuit 2. With switch #1 open, operation of motor is on an on-off basis from photoresistor With switch #1 closed, the timing circuit is added to give time delay feature	A. Discuss delayed action-sensitive control circuits 1. Purpose-perform automatic functions with time delay 2. Applications a. In heating systems, to turn on a blower for a short period of time when smoke is detected in the stack b. In garages, to open doors for a short period of time to allow passage of a vehicle

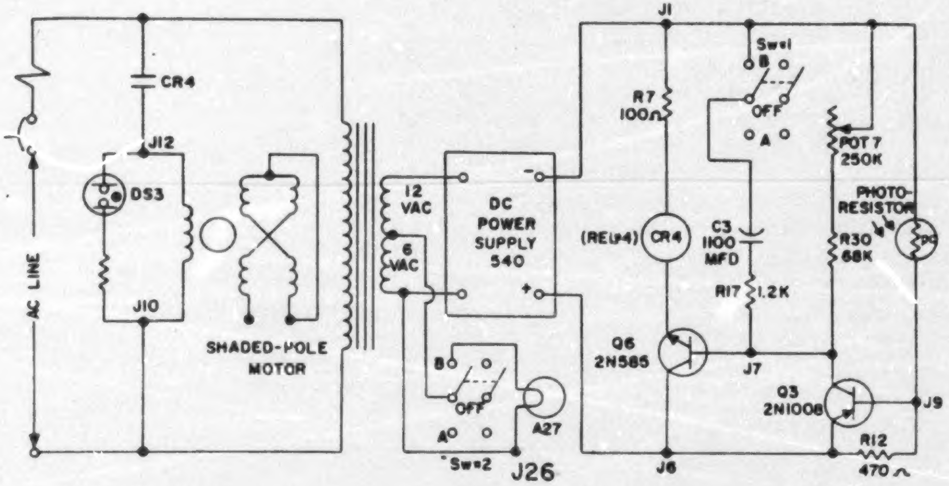

CR4
J12
DS3
AC LINE
J10
SHADED-POLE MOTOR
12 VAC
6 VAC
DC POWER SUPPLY 540
B
OFF
A
Sw#2
J26
A27
J1
R7 100Ω
Sw#1
B
OFF
A
POT 7 250K
PHOTO-RESISTOR
R30 68K
PC
(RE#4)
CR4
C3 1100 MFD
R17 1.2K
Q6 2N585
J7
Q3 2N1008
J9
R12 470Ω
J6

Fig. #61 Delayed Action Light-Sensitive Control Circuit

34. Wire a relay memory actuator circuit

A. Discuss how an extension of the basic memory circuit permits recording of multiple events

B. Develop job circuit on chalkboard. (See Fig. #62)

C. Demonstrate
   1. Job wiring for circuit
   2. How activation of sensing element causes relay CR1 to lockup, keeping lamp DS2 on until reset SW4 is pressed

A. Discuss the memory actuator
   1. Purpose: to acknowledge and remember events which may have taken place during time absence of a machine attendant
   2. Application: registering whether or not
      a. Telephones rang
      b. Lights were turned on
      c. Doors were opened
      d. Burglar alarms were tripped

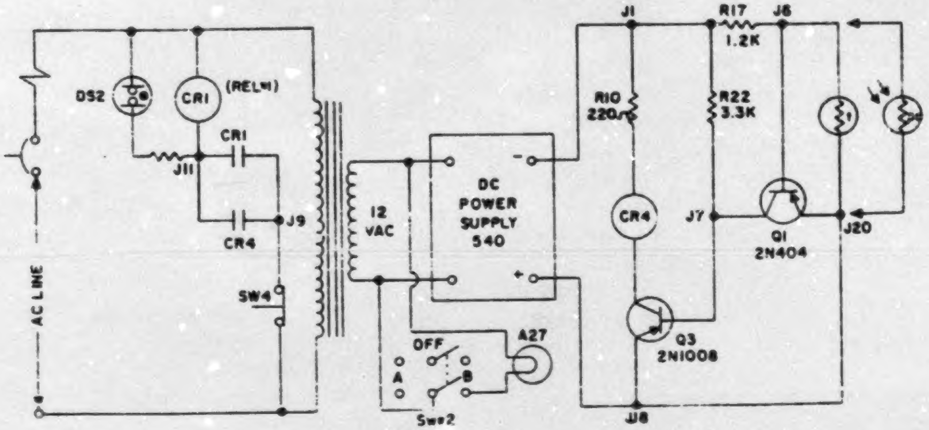

DS2
CR1
(RELAY)
CR1
J11
J9
CR4
SW4
AC LINE
12 VAC
DC POWER SUPPLY 540
OFF
A
B
A27
Sw#2
J1
R17 1.2K
J6
R10 220Ω
R22 3.3K
CR4
J7
Q1 2N404
J20
Q3 2N1008
J8

Fig. #62 Relay Memory Actuator

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information

35. Wire a material selection and counting circuit using photoelectric control	A. Discuss industrial applications for the circuit
	B. Develop job circuit on chalkboard (See Fig. #63)
	C. Demonstrate
	  1. Job wiring for circuit
	  2. How, when an opaque material or object breaks light source, lamp DS1 will light.
	  How setting of potentiometer permits sorting of translucent materials of various thicknesses
		A. Discuss selection and counting circuits
		  1. Purpose: count and sort materials
		  2. Methods
		    a. Reflected light is used to measure the glossiness of a surface in addition to counting and color discrimination
		    b. Transmitted light is used to measure thickness, discriminate between colors and count
		  3. Operations
		    a. Counting: interruption of an electric eye generates a signal which causes a counter to move one digit
		    b. Color discrimination: accomplished by proper choice of colors for light source and sensing element
		    c. Thickness: accomplished by gauging amount of light transmitted through a material

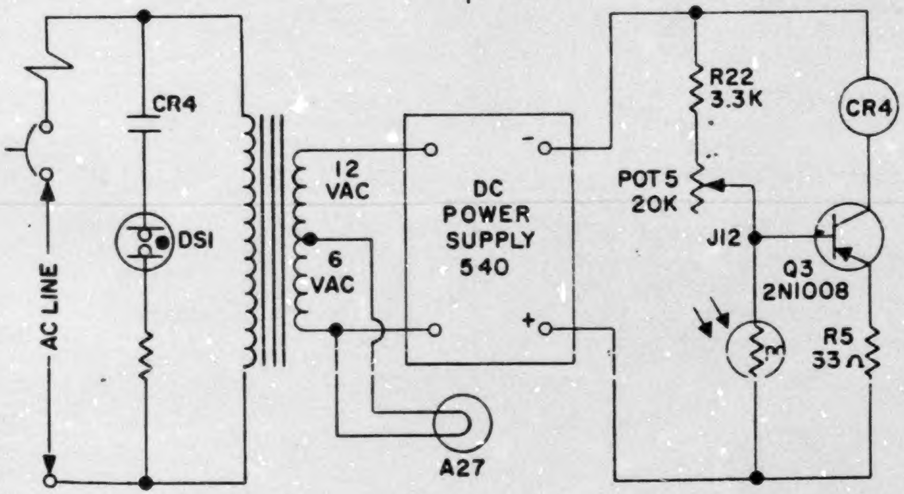


Fig. #63 Experimental Photoelectric Circuit

36. Wire a transistorized liquid level circuit with an electrode-sensing element

A. Discuss the construction and function of float switches. Reference can be made to the float in a toilet tank. Discuss the electrode-sensing element.

B. Develop job circuit on chalkboard (See Fig. #64)

C. Demonstrate
   1. Job wiring for circuit
   2. Operation of motor and lamp from fluid controls tank
      1. Potentiometer adjusts conduction point for transistor
      2. Liquid level determines resistance values between electrodes rise in level reduces resistance causing transistor conductor

A. Discuss liquid level control
   1. Review use of float switches
   2. Advantage of electrode sensing
      Method: reliable, sensitivity, little maintenance
   3. Disadvantage: cannot be used in corrosive or caustic environment
   4. Applications: start and stop pumps, open and close valves; operate alarm and signal lights; liquid carry over detection

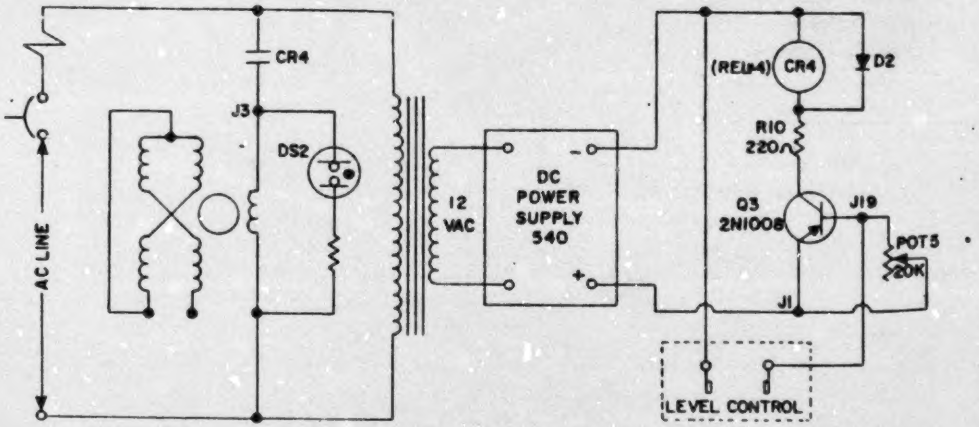


Fig. #64 Transistorized Liquid Level Control With Electrode-Sensing Element

Tasks	TEACHING CONTENT Development of Skills	 Development of Related Information
37. Wire a liquid-level and contamination-control circuit	A. Develop job circuit on chalkboard (See Fig. #65) B. Demonstrate 1. Job wiring for circuit 2. Circuit operation a. Simulate liquid contamination by adding table salt b. Contamination causes transistor to start shaded pole motor through relay CR4. This motor simulates pump action c. Lowering of liquid level operates float switch causing universal motor to start through relay CR3. This motor simulates clean water intake action	A. Discuss the purpose for liquid contamination control B. Review the construction and function of the sensing electrodes and float switch C. Review construction of the shaded pole and universal motors

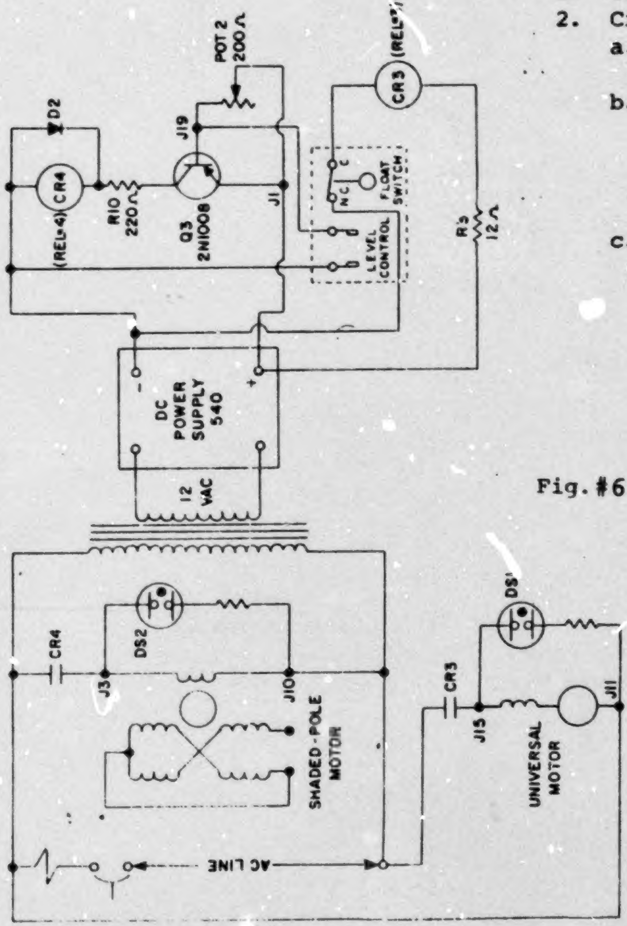

D2
CR4
(REL-4)
R10 220Ω
J19
Q3 2N1008
POT 2 200Ω
J11
CR3
(REL-3)
NC
C
FLOAT SWITCH
LEVEL CONTROL
R3 12Ω
−
+
DC POWER SUPPLY 540
12 VAC
DS2
CR4
J3
J10
SHADED-POLE MOTOR
DS1
CR3
J15
J11
UNIVERSAL MOTOR
AC LINE

Fig. #65

Liquid Level and Contamination Control Circuit

38. Wire a liquid level control circuit using an SCR and triac	A. Develop the job circuit on the chalkboard (See Fig. #66) B. Demonstrate 1. Job wiring for the circuit 2. Operation of circuit a. At low liquid level, the SCR triggers the triac and the pump motor operates b. At upper liquid level, gate current decreases, the SCR turns off causing the triac and motor to also turn off	A. Review the construction and function of the following 1. Triac 2. SCR 3. Transistor 4. Zenor diode 5. Thyristor 6. Thermister 7. Semi-conductor 8. Phototransistor 9. Photoresistor 10. Diac

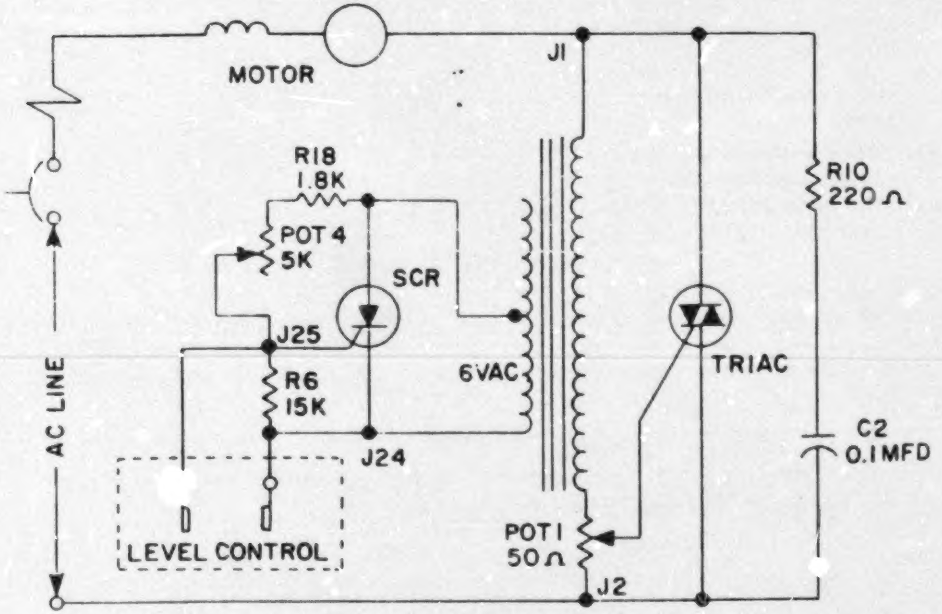

MOTOR
J1
R18
1.8K
POT 4
5K
SCR
J25
R6
15K
J24
6VAC
LEVEL CONTROL
AC LINE
TRIAC
R10
220Ω
C2
0.1MFD
POT1
50Ω
J2

Fig. #66 Liquid Level Control Using an SCR and a Triac

Tasks	TEACHING CONTENT	
	Development of Skills	Development of Related Information
39. Troubleshoot faulty wiring in solid-state control circuits	A. Discuss the meaning and importance of troubleshooting B. Develop the job circuit on the chalkboard (See Fig. #67) C. Demonstrate 1. Job wiring for circuit 2. Making corrections in circuit a. Correct power supply b. Correct connections to transistors QG and Q5 c. Testing circuit	A. Discuss rules for troubleshooting solid-state control circuits 1. Study problem and analyze probable causes 2. Use a systematic approach in analyzing the circuit branch-by-branch in sequence. Do not make random measurements and changes 3. Suggested order for checking a. Input voltage b. Power and condition of load c. Wiring: for shorts and breaks d. Active components (solid-state devices) Check performance e. Passive components (capacitors, resistors) Check for opens, shorts, or improper values 4. Make only one change in the circuit at a time

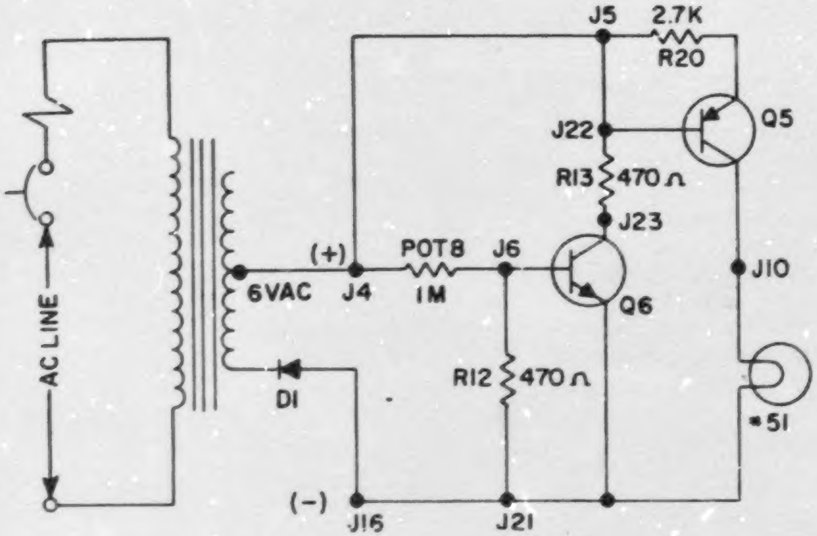


Fig. #67 Faulty Circuit

40. Troubleshoot thyristor circuit malfunctions

A. Discuss modern trends toward modular construction of electronic packaging
B. Develop job circuit on chalkboard (See Fig. #68)
C. Demonstrate
  1. Job wiring for circuit
  2. Making corrections in circuit
    a. Reconnect SCR
    b. Replacing resistor R30 with R22 (3.3K Ohms)
    c. Install potentiometer P6 to SCR gate and resistor 23
    d. Checking functions

A. Discuss electronic troubleshooting
  1. Steps in troubleshooting
    a. Study entire system and know what it is supposed to do
    b. Study each subsystem and learn their functions
    c. Study the major circuits and circuit components in each system and analyze their operation and purpose
  2. Trends in electronic packing
    a. Modular construction
    b. Replacing of entire sections
    c. Elimination of rewiring and resoldering

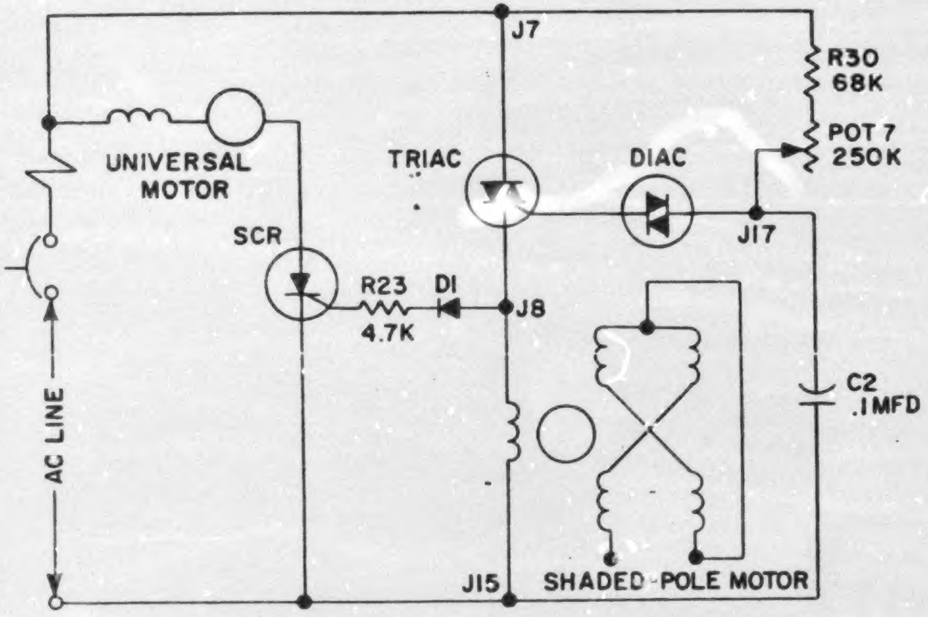

J7
R30
68K
POT 7
250K
UNIVERSAL
MOTOR
TRIAC
DIAC
J17
SCR
R23
4.7K
DI
J8
AC LINE
C2
.1MFD
J15
SHADED-POLE MOTOR

Fig. #68 Schematic Diagram of Malfunctioning Thyristor Circuit

Unit VII: Transformers

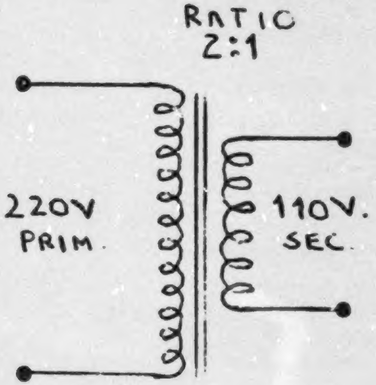
Level Three: Motors and Controls
Suggested Time: *10 Hours / 15 Periods*

Performance Objectives

Upon completion of this unit the student will be able to:

- Connect a single-phase transformer for step-down operations, 220/110 volts. Test and record results.
- Connect three single-phase, step-down transformers for delta-delta. Test and record results.
- Connect an auto-transformer for step-down and step-up operation. Test and record results.

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information

1. Connect a single-phase transformer for step-down operation, 220/110 volts. Test and record results.

 	
Fig. #1
	1. Display s single phase transformer and discribe its construction and purpose
	2. Explain meaning of step-up and step-down
	3. Develop circuit connection on chalk-board
	4. Demonstrate
	   1. Connecting primary to source of supply
	   2. Checking secondary voltage with a voltmeter
		A. Discuss transformers principles
		   1. Definition
		   2. Basic principle of operation
		   3. Core types
		      a. Core
		      b. Shell
		      c. Cross
		B. Review use of voltmeter
		   1. Emphasize necessary precautions in selecting the correct operating range

2. Connect two single-phase step-up transformers for parallel-parallel operation. Test and record results.

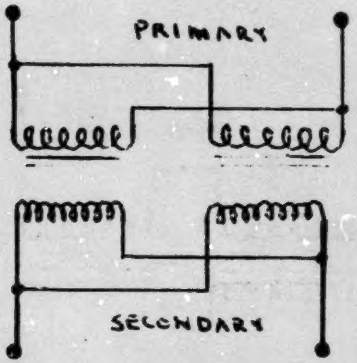
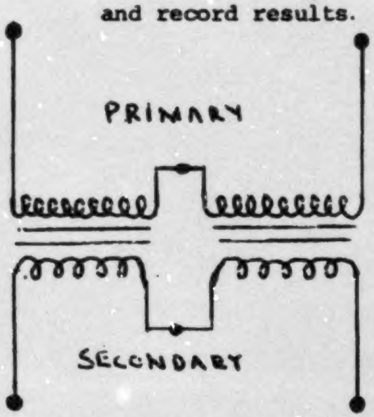


Fig. #2

A. Discuss reasons for connecting transformers in multiple
B. Review parallel circuits
C. Develop connection circuit on chalkboard
D. Demonstrate
    1. Connecting primaries in parallels
    2. Connecting secondaries in parallels
    3. Checking voltage across primaries
    4. Checking voltage at secondaries

A. Discuss transformer principles
    1. Voltage ratio
    2. Turn ratio
    3. Current ratio
    4. Efficiency
    5. Ratio of power input to power output

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
3. Connect two single-phase step-down transformers for series-series operation. Test and record results.  Fig. #3	A. Discuss reasons for connecting transformers in series B. Review series circuits C. Develop circuit connection on chalkboard D. Demonstrate 1. Connecting primaries in series 2. Connecting secondaries in series 3. Checking voltage of each primary and the series primaries 4. Repeating an secondary side	A. Discuss single-phase transformers 1. Double wound 2. Markings 3. Additive polarity 4. Subtractive polarity

4. Connect two single-phase step-up transformers for series-parallel operation. Test and record results.

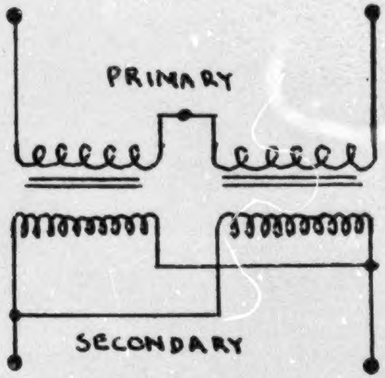


Fig. #4

A. Discuss purpose for the series-parallel connection of transformers
B. Develop circuit connection on chalk-board
C. Connect primaries in series
D. Connect secondaries in parallel
E. Checking voltage of each primary and the series primaries
F. Checking the voltage of the paralleled secondaries

A. Discuss single phase transformers connected for
    1. Series primary-series secondary
    2. Parallel primary-parallel secondary
    3. Compare voltage and ampacity features

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	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
5. Connect two single-phase step-down transformers for parallel-series operation. Test and record results.	A. Discuss purpose for parallel-series operation of single phase transformers B. Develop circuit connection on chalkboard C. Connect primaries in paralles D. Connect secondaries in series E. Checking voltage of paralleled primaries F. Checking voltage of each secondary and the series secondaries	A. Discuss transformers cooling methods 1. Air cooled 2. Forced air 3. Oil immersed 4. Water circulated

6. Connect three single-phase step-down transformers for delta-delta. Test and record results.

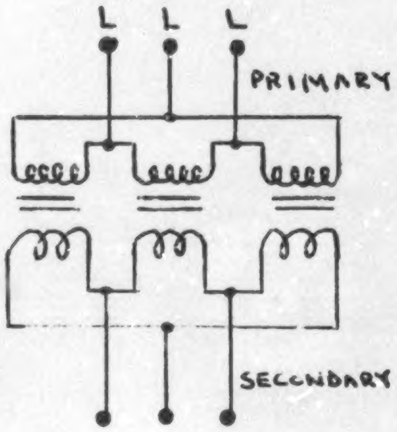


Fig. #5

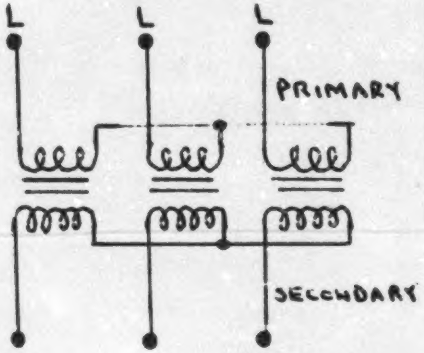
A. Display a three-phase transformer bank and discuss its applications

B. Develop circuit connection for a delta-delta on chalkboard

C. Demonstrate
   1. Connecting the primary delta
   2. Connecting the secondary delta
   3. Checking voltage at each transformer on the primary and secondary sides
      a. Coil voltage
      b. Line voltage

A. Discuss the delta-delta transformers connection
   1. Circuitry
   2. Line and coil voltage relationships
   3. Line and coil current relationships
   4. Applications

B. Discuss the advantages of three individual single-phase transformers as compared to a three-phase transformer

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
7. Connect three single-phase step-up transformers for wye-wye. Test and record results.  Fig. #6	A. Display a three-phase transformer bank and review its applications B. Develop circuit connection for a wye-wye on chalkboard C. Demonstrate: 1. Connecting the primary wye 2. Connecting the secondary wye 3. Checking voltage at each transformer on the primary and secondary sides a. Coil voltage b. Line voltage	A. Discuss the wye-wye transformer connection 1. Circuitry 2. Line and coil voltage relationships 3. Line and coil current relationships 4. Applications B. Discuss code regulations for transformers (N.E.C., Article 450) 1. Location 2. Overcurrent protection 3. Secondary ties

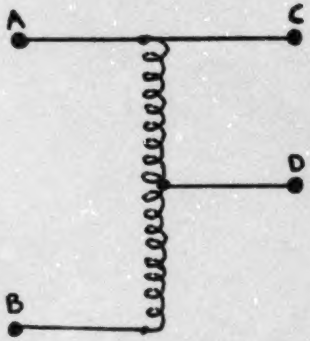
8. Connect a three-phase step-up transformer for delta-wye. Test and record results.

A. Display a three-phase transformer and discuss its application
B. Develop circuit connection for delta-wye on the chalkboard
C. Demonstrate
    1. Connecting the primary delta
    2. Connecting the secondary wye
    3. Checking voltage of transformer on the primary and secondary sides
        a. Coil voltage
        b. Line voltage

A. Discuss the advantage and disadvantages of three-phase transformers
B. Discuss the delta-wye transformer connection
    1. Circuitry
    2. Line and coil voltage relation
    3. Line and coil current relationships
    4. Applications

	TEACHING CONTENT	
Tasks	Development of Skills	Development of Related Information
9. Connect a three-phase step-up transformer for wye-delta. Test and record results.	A. Display a three- phase transformer and review its applications B. Develop circuit connection for wye-delta on chalkboard C. Demonstrate: 1. Connecting the primary wye 2. Connecting the secondary delta 3. Checking voltage of transformer on the primary and secondary sides a. Coil voltage b. Line voltage	A. Discuss the wye-delta transformer connection 1. Circuitry 2. Line and coil voltage relationships 3. Line and coil current relationships 4. Applications B. Discuss code regulations for transformers (N.E.C., Article 450) 1. Parallel operation 2. Guarding 3. Ventilation 4. Grounding

10. Connect an auto-transformer for step-down and step-up operation. Test and record results.



STEP DOWN: LINE TO A-B
STEP UP : LINE TO C-D

Fig. #7

A. Display an auto-transformer and compare it to the conventional type
B. Develop circuit connection for step-down and step-up operation on the chalkboard
C. Demonstrate
    1. Connecting high turns side to proper source of supply
    2. Checking voltage at secondary
    3. Connecting low turns side to proper source of supply
    4. Checking voltage at secondary

A. Discuss auto transformers
    1. Definition
    2. Construction
    3. Voltage and turns relationship
    4. Current and turns relationship
    5. Applications
    6. Limitations
B. Discuss code regulations for transformers (N.E.C., Article 450)
    1. Grounding auto transformers
    2. Marking
    3. Terminal wiring space

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Sample Lesson Plan

TOPIC: A.C. Motor Controls

AIM: To wire a three-phase induction motor to be operated by an across the line magnetic starter controlled from one start-stop switch.

INSTRUCTIONAL OBJECTIVE

A. That students will demonstrate, in writing, their knowledge of the construction, operation, basic circuitry and advantages of magnetic starters.

B. That students will be able to wire the circuit in E.M.T. to required specifications so that the motor can be started and stopped from a remote location.

PREPARATION

A. Have magnetic starter and control station

B. Have colored chalk for circuit development

C. Have equipment layout diagram on chalkboard

D. Have equipment mounted on demonstration board

MOTIVATION: Discuss wide use of magnetic starters in industry and relate several applications for their installation.

PRESENTATION

A. Discuss the advantages of magnetic control.
B. Describe and demonstrate operation of the starter.
C. Develop schematic and wiring diagrams, with student assisting, from layout diagram.

SUMMARY

A. Review advantages and applications for magnetic control.
B. Review basic circuits in a starter.

ASSIGNMENT

A. Students are to install circuit in their work stations to specifications for a grade.
B. Students are to complete diagrams in their notebooks using appropriate colors.

REFERENCES: Electric Motor Repair, Robert Rosenberg
Electrical Principles and Practices, James Adams

KEY QUESTIONS

1. Give three advantages of magnetic starting over manual starters.
2. What is the purpose of the control circuit?
3. What is the normal position of a start button?
4. In which starter circuit are the heaters wired?
5. What is the purpose of the sealing contacts?

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3. Methods and materials used sucessfully:

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